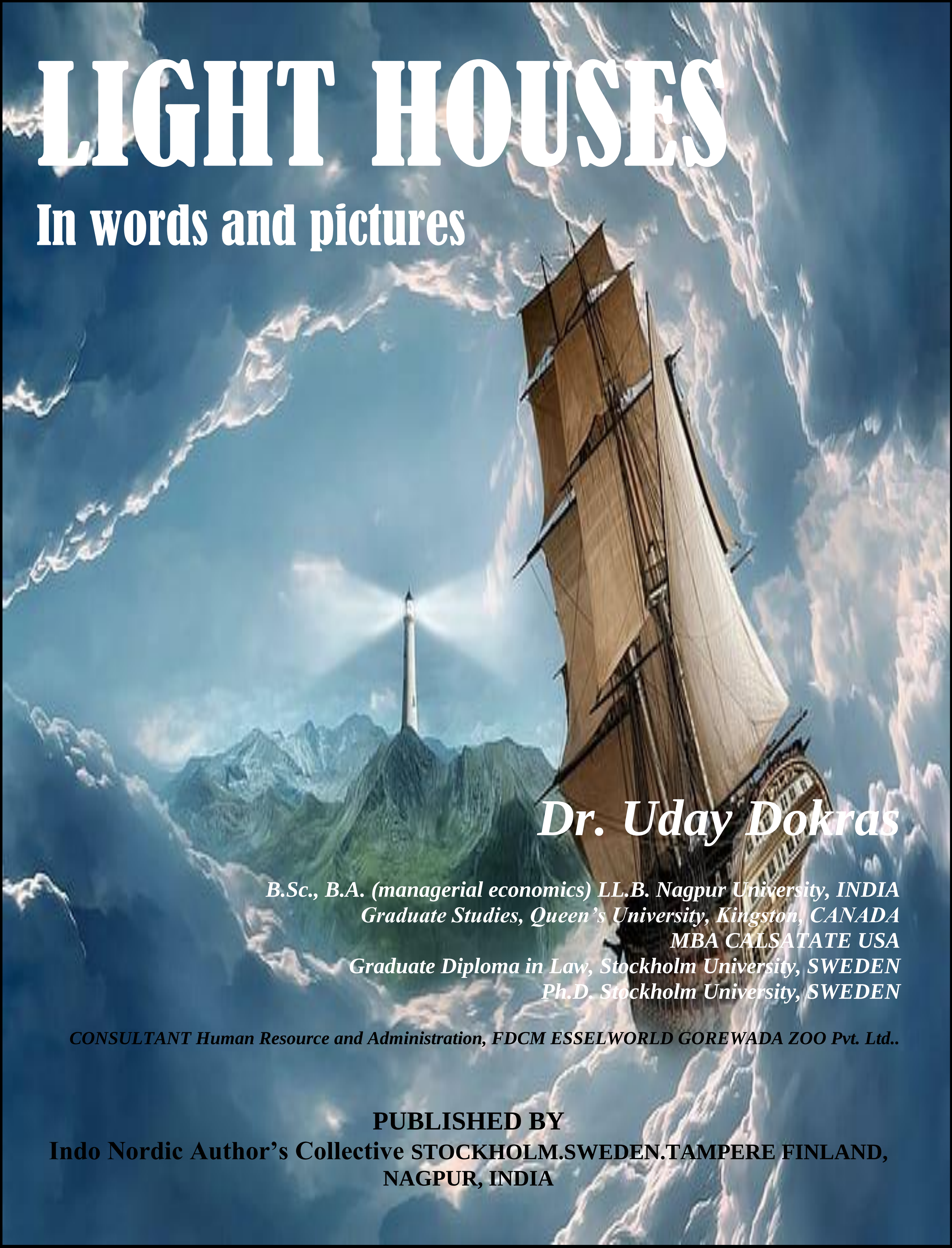

LIGHT HOUSES

In words and pictures

Dr. Uday Dokras

B.Sc., B.A. (managerial economics) LL.B. Nagpur University, INDIA
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Lighthouse in the Storm

Poem by Norma Beaird

Sometimes my life is like the sea,
And raging waters cover me,
Sometimes my path is smooth as glass,
And then a rainstorm comes to pass.
But if a storm cloud brings you pain,
Remember rainbows follow rain,
And though the journey has you worn,
The darkest night will lead to dawn,
When there's Lighthouse in the storm.

There is a cross at Calvary,
That covers those who will believe,
And when your boat in life is tossed,
You'll find your answer is the cross.
And if a flood begins to rise,
Sustain your faith in Jesus Christ,
So you need never be alarmed,
For He will keep you safe from harm,
When there's a Lighthouse in the storm.

There is a Lighthouse in the storm,
Though my sails are beat and torn,
There is a Light that holds the key,
To peace of mind on troubled seas,
And as His light is shining bright,
I seem to lose my fear of night,
For when you're safe within God's arms,
You know you'll never be alone,*For He's the Lighthouse in the storm.*

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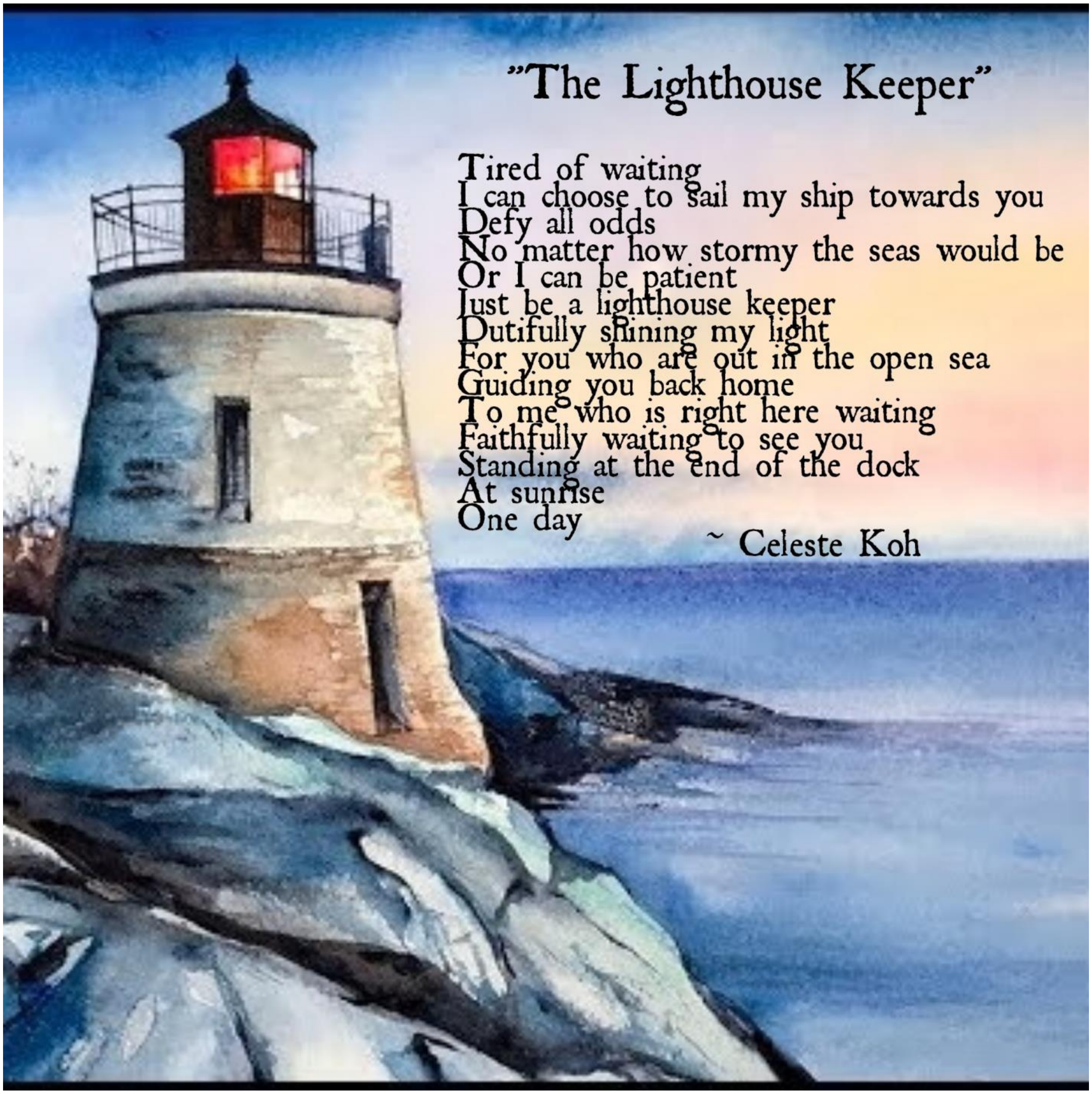
HOW THIS BOOK IS STRUCTURED



"The Lighthouse Keeper"

Tired of waiting
I can choose to sail my ship towards you
Defy all odds
No matter how stormy the seas would be
Or I can be patient
Just be a lighthouse keeper
Dutifully shining my light
For you who are out in the open sea
Guiding you back home
To me who is right here waiting
Faithfully waiting to see you
Standing at the end of the dock
At sunrise
One day

~ Celeste Koh

There are 1000s of poems on the lighthouse, two of my favourite you have been presented to read. Similarly, there are many articles. Especially those that chronicle the history, density and morphology of these towers add to the invaluable knowledge of this Tower realm. I have produced many verbatim with proper acknowledgments to those who painstakingly added the words after copious research. Thank you all. There was no other way to go. I hope you will relish my supplementary diction to that of these brilliant authors. Au revior. à plus

ACKNOWLEDGMENT

To Alexander the Great I own my debt.

As I progressed through my research on the light house of Alexandria I became intrigued and fascinated by the world of light houses.

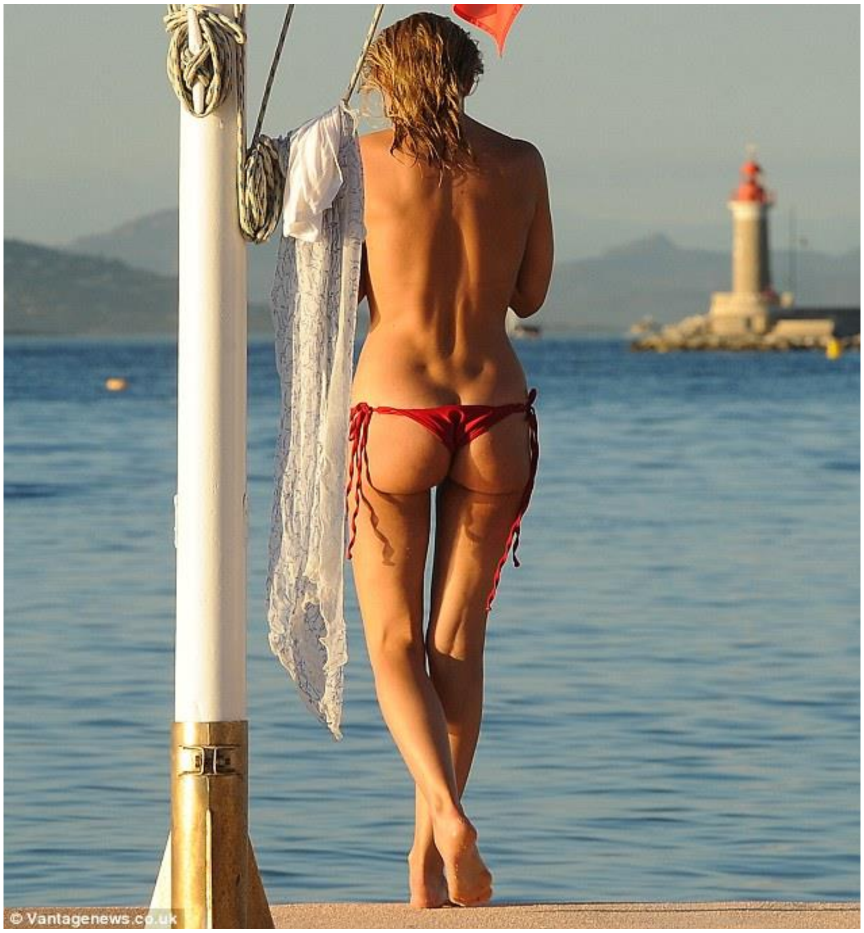
The terrain, tempest, temperament, technology, tedium, topography, territory, typhoons, tornedos, hurricanes, geography, oceanography, storms, weather conditions, climate, construction, erection, edifice, structure, creation, landscape, environment, mechanics, engineering, piling, destruction, formation, electronics, electricals, mechanicals, civil engineering, mechanics, physics, history, rogue waves, tsunamis, redeemership all arrested my curiosity and attention.

I then stumbled upon this veritable collection of Light House pictures placed on-line that add much romance to the tales of the mariners and their savior.

We all have light houses in our lives. Those that flash and save us from making a wreck of ourselves just in the nick of time. These light houses I shall keep nameless, but in my heart I remember them and when the storms arise, their bacon flashes anew.

Writing this book has been an incredible journey and all thanks to that dynamic Macedonian prince, who unfortunately, lacked a light house in his own life.

INTRODUCTION



"The voyage along the coast of this sea [the Mediterranean] is exceedingly long, and any landing is especially difficult; for from Paraetonium in Libya as far as Iopê in Coele-Syria, a voyage along the coast of some five thousand stades, there is not to be found a safe harbour except Pharos. And, apart from these considerations, a sandbank extends along practically the whole length of Egypt, not discernible to any who approach without previous experience of these waters. Consequently those who think that they have escaped the peril of the sea, and in their ignorance turn with gladness towards the shore, suffer unexpected shipwreck when their vessels suddenly run aground; and now and then mariners who cannot see land in time because the country lies so low are cast ashore before they realize it, some of them on marshy and swampy places and others on a desert region."

Diodorus Siculus, *Library of History (I.31.2-5)*

Introduction: There are numerous new studies examining the design of buildings in seaside locations. The chapters therein discuss design for various locations and seaside climates and include information regarding climate, materials, concepts of cooling and heating, vegetation and micro-climate, and weather conditions and sustainability. They provide architects, engineers, builders, and students with design examples and applications that will enable them to design and build comfortable, cost-effective and sustainable buildings in maritime zones including lighthouses. The purpose of this book is not to compete with them. A single comprehensive book featuring all essential requisites to understanding the light house construction will go into at least 2000 pages. So vast is the domain – the pictures and etchings themselves will garner a 1000 pages to say the least. The reason is quite simple. The history of light houses is an ancient one. As you will read in my book-“ *The light house of Alexandria”;* the first of its kind started construction almost 2000 years ago

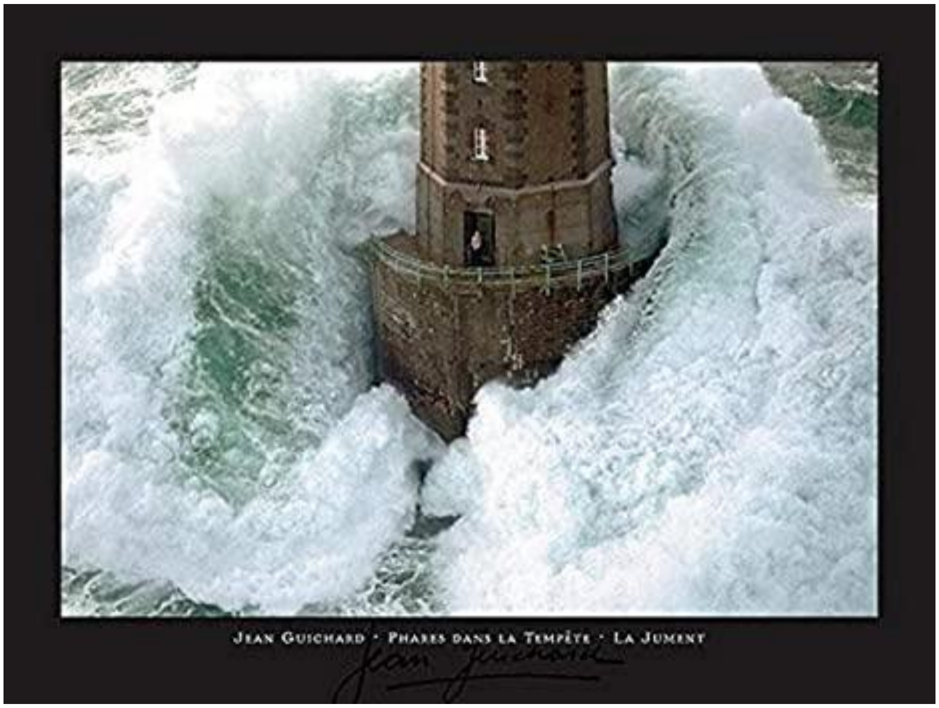
The lighthouse however offers a different perspective. As the name suggests- it is a house of light. The tower served principally as a support for the lantern which housed the optics. The lantern was typically constructed of cast iron; round, square, octagonal, or hexagonal-shaped, and surrounded by a stone or cast-iron gallery. Access to the lantern room was via stone, wood, or cast iron stairs which either wound around a central column or spiraled along the interior sides of the tower walls.

Generally, coastal lighthouses on the low, flat coasts tended to have tall towers to elevate the lens high enough so the light may be seen many miles at sea; whereas lighthouses on the west coast tended to have short towers built on sea cliffs high enough to project the light many miles at sea. Several light stations on the northeastern coast of the USA, were also located to take advantage of naturally high elevation sites, such as Block Island Southeast Lighthouse, Rhode Island, and Monhegan Island Lighthouse, Maine. Ironically, the low clouds so characteristic of the west coast caused some station sites at high elevations to be moved to lower altitudes with taller towers in order to get the light below the low cloud levels, but high enough to be visible to ships at sea.

Lighthouse Construction before the mid-nineteenth century, lighthouse construction technology required solid rock or other stable foundation soils; onshore towers sometimes proved inadequate to warn of a shoal located offshore. In some locations a lighted buoy or a lightship solved this problem. Types Politics, need, cost, location, and geography of the site, as well as technology available at the time of construction influence lighthouse designs.

Riverine and estuarine environments, however, often had unstable muddy and/or sandy bottoms which could not support the heavy masonry towers then in vogue. In some areas, more often than not, the development of newer technology using screwpile, caisson, and skeletal tower lighthouse construction was essential to adequately light these marine hazards.

As technology advanced, stations were improved or even moved to better manage hazards such as offshore shoals. Lighthouses were made from a variety of materials including wood, stone, brick, reinforced concrete, iron, steel, and even aluminum and fiberglass. Lighthouses were built on land, in the water, on islands, on top of ledges and cliffs, on breakwaters and piers, on caissons, and at least five are on fort walls. Some light towers are standalone structures, while others are attached or integral to the keeper's quarters or fog signal building. Until the adoption of the Fresnel lens in the United States in the 1850s, there was no uniform design for the lantern. Pre-1850s lanterns are rare and are often referred to as old style or bird cage lanterns because of their bird cage appearance. Selkirk (Salmon River) Lighthouse, New York, built in 1838, retains its bird cage lantern.



The bird cage lantern on Cape Henry Lighthouse, Virginia, is a reconstruction of one built in 1792. Many pre-1850s light towers had their older lantern removed and new cast-iron lanterns installed when Fresnel lenses were added to a light station; most light stations in the United States were fitted with Fresnel lenses by 1860. In addition to the replacement of the lantern, the tower supporting the lantern was often modified to accommodate the larger lenses. Fresnel lenses were developed in seven standard sizes, depending on need. The largest first-order lenses were designed for important coastal sites while the sixth order, the smallest, was designed for small harbors and rivers (the seventh size was a third-andone-half order). The meso radial and hyper radial were two additional lens sizes that were not used in the U.S. with the one exception, Makapuu Light, Hawaii. To accommodate these new lenses the Lighthouse Board designed four pre-made ready-to-assemble cast-iron lanterns for first, second, third, and fourth orders.

Living close to the sea could support better mental health in England's poorest urban communities, finds a new study published today in the journal *Health and Place*.[1]The coast is a dynamic place and its dynamism makes it susceptible to stresses and changes in a number of ways. Because the coast is where the land interacts with the sea, it is open to the action of wind, waves, tides, and currents that not only erode the shore but also can expand it with sedimentary deposits. The coastline is a unique condition where a fusion of many forces occurs. There are two main ways the coastline has been addressed: the manmade and the natural.

Pic by Nadine Bouler

The goal of all coastal buildings especially the building the coasts which are highly vulnerable to disasters should be to resist the different fluctuating forces acting on a coast. Also to maintain a good life of the building by using the suitable materials for the moisture and pressure level acting on it. The high energy generated due to multiple forces acting can be conserved and used. Proper design principles if established will generate s safer techniques for building designs on coastal areas.

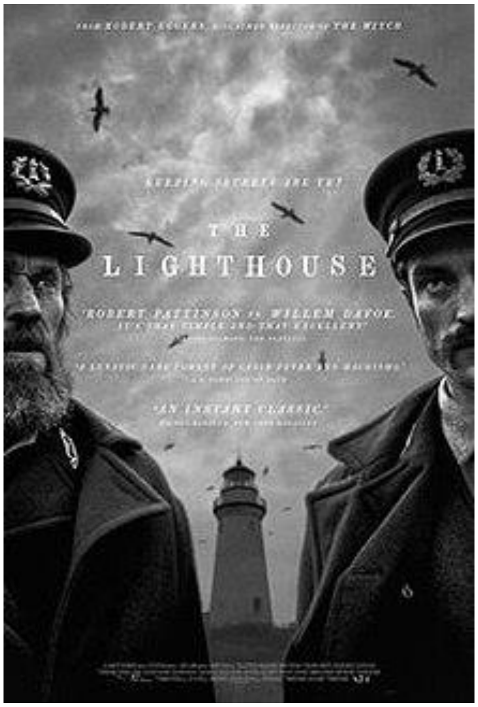
To the weary sailors of yesteryear, it represents the final stretch -- and perhaps the most hazardous portion -- of a long voyage. To modern-day aficionados, it is a glimmering monument to the history of a maritime community. But whatever meaning gets attached to it, a lighthouse is something far simpler: a tower and a beacon. In an era before GPS and other navigational apparatuses, lighthouses served two primary purposes. The first was illuminating waterways made treacherous by shoals, reefs, rocks and other hazards as ships left the open ocean and pulled into port. Most lighthouses also include fog signals such as horns, bells or cannons, which sound to warn ships of hazards during periods of low visibility.

My fascination for the tower that stands against the unpredictable fury of the ocean began with my last book on the LightHouse at Alexandria. I am also inspired by Elinor DeWire who began her career as an author by writing freelance stories about her passion for lighthouses for a Florida newspaper.Later she wrote her first book, *Guide to Florida Lighthouses,* which was published by Pineapple Press in 1987. From 1991-2000 DeWire wrote two columns, "Lifelines" and "Whale Oil and Wicks" for the National Oceanic & Atmospheric Administration's *Mariners Weather Log*.

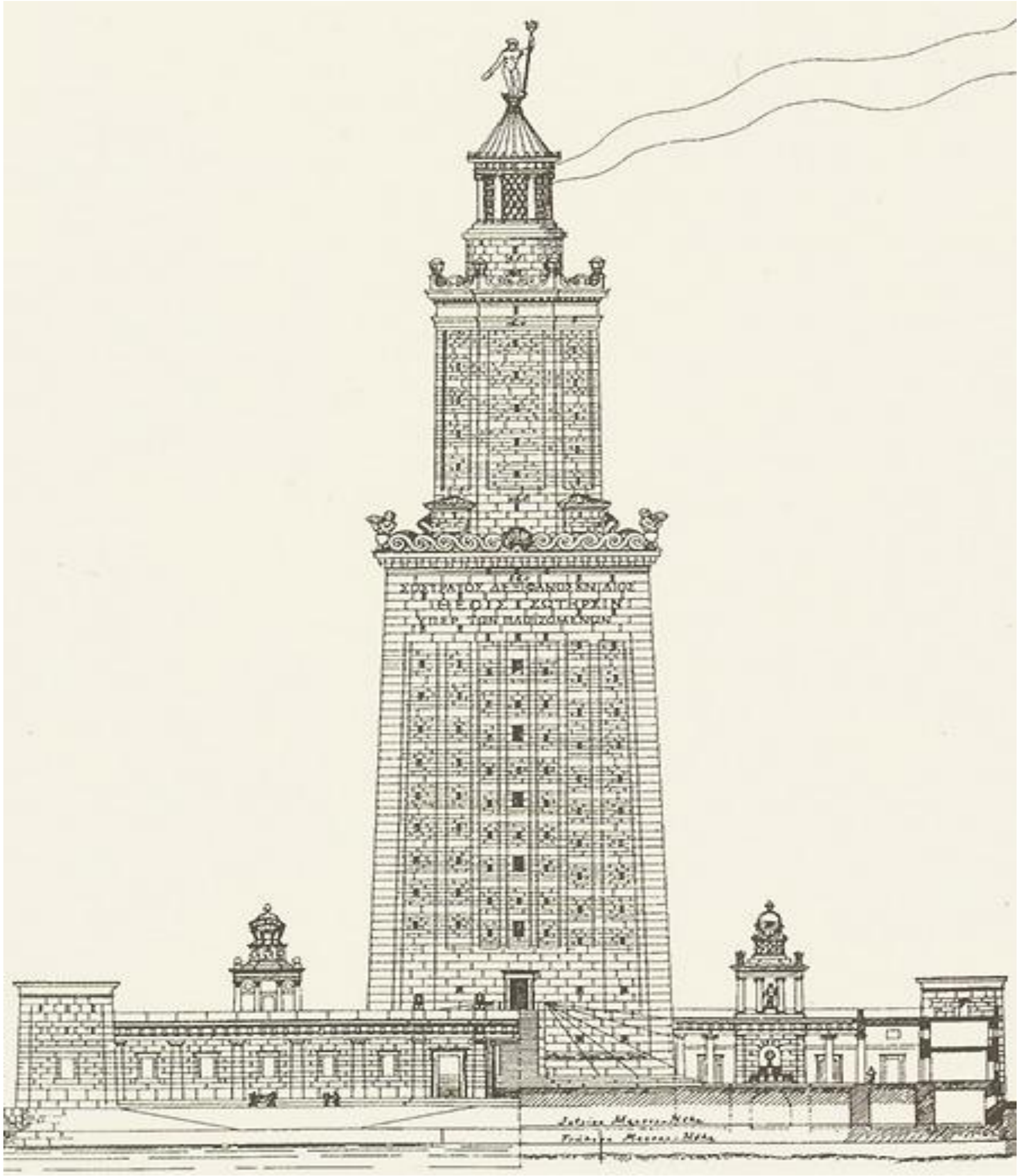
Since that time DeWire has authored more than twenty books about lighthouses, including a series of illustrated, quick-reference e-books about lighthouses, the "Itty-Bitty-Kitty Guides". She has also written romance novels, plus four books and a number of articles about amateur astronomy and sky watching. She has continued to contribute articles about lighthouses to magazines and newspapers, including columns titled "Shore Almanac," "Away from the Bay," "Kids on the Beam," and "Liquidized Lore."

She has been a regular contributor to *Weatherwise Magazine*, *The Beachcomber*, *Lighthouse Digest*", and *The Keepers Log*, journal of the U.S. Lighthouse Society. She maintains a blog which also focuses on lighthouses and related nautical topics, and has written fiction for several magazines. DeWire is also a public speaker about lighthouse history and lore, and she volunteers for several nonprofit groups devoted to lighthouse preservation and education.

"Lighthouses are not just stone, brick, metal, and glass. There's a human story at every lighthouse; that's the story I want to tell." She said . I doubt very much if this book can capture the human side of the waves- the petrified sailors in the storm or the loneliness of theWickies (lighthouse keepers). But I hope that in the 500 pages or so, I will cast a beam on this romantic and fascinating world of the Light Houses.


THE
LIGHTHOUSE
'ROBERT PATTINSON VS. WILLEM DAFOE.'
"AN INSTANT CLASSIC."

The Lighthouse is a 2019 psychological horror and drama film directed and produced by Robert Eggers, who co-wrote the screenplay with his brother Max Eggers. An international co-production of the United States and Canada, the film was shot in black-and-white. Willem Dafoe and Robert Pattinson starred as two lighthouse keepers who start to lose their sanity when a storm strands them on the remote island where they are stationed.



The light house at Alexandria also known as Tower of Pharos after the name of the island it stands on

REFERENCES

1. *Researchers from the University of Exeter used survey data from nearly 26,000 respondents in their analysis into the wellbeing effects of being beside the sea revealed that living in large towns and cities near to England's coastline is linked with better mental health for those in the lowest earning households. Joanne K. Garrett, Theodore J. Clitherow, Mathew P. White, Benedict W. Wheeler, Lora E. Fleming. Coastal proximity and mental health among urban adults in England: The moderating effect of household income. Health & Place, 2019*

Chapter I

Navigating in the Fog

Many years ago, people decided to explore the waters by boat. During the day they could find their way back to the landing place by looking for a pile of rocks that had been left there. These were the first daymarks. But how could they find their way home at night? Since much of the shoreline looked very similar, friends had to light a bonfire on a high point to guide them to the right landing area. Still later they used a pole or a tripod to hang a metal basket containing a fire as a method of signaling. Our first lighthouses were actually given to us by Nature herself. Sailors sometimes used landmarks such as glowing volcanoes to guide them. In the Ancient World, trading ships were eventually built enabling navigators to sail long distances to buy and sell goods. In the days of wooden ships with sails, the wind and waves could easily push them against the rocks and wreck them.

And so, the need for lighthouses as warning signals arose. One of the Seven Wonders of the Ancient World was a lighthouse - the famous Pharos of Alexandria, Egypt. It is the first one that is recorded in history and was built about 280 B.C. Those records tell us that it was the tallest one ever built -450 ft. (comparable to a 45 story skyscraper) and used an open fire at the top as a source of light. Can you imagine being the keeper, climbing to the top to light the fire, and then

forgetting the matches or whatever was used in those days to start a fire? This fantastic structure survived for 1500 years until it was completely destroyed by an earthquake in the 14th Century. Slave labor was used to build it, and it took twenty long years to complete. It was a three part tower with a square base, a second story with eight sides and a narrow, taller; round third story.
At night they believe its lighted fire could be seen for thirty miles, whereas by day it produced a column of smoke for a daymark. Today we call people who study (or are interested in) lighthouses pharologists. The name comes from that famous lighthouse. Wood fires were the earliest illuminants. As lighthouses proliferated, lamps powered by coal, whale oil, kerosene and other fuels became commonplace. One of the most novel lighthouse inventions, the Fresnel lens, came along in 1822 and used a network of prisms to magnify a small amount of light and cast a beam over distances of 20 miles (32.18 kilometers) or more. The lens was widely used across the pond, but under Stephen Pleasant, who oversaw lighthouses from 1820 to 1852, U.S. lighthouses were equipped with low-cost alternatives. Soon after the establishment of the Lighthouse Board in 1852, all lighthouses in the United States were equipped with Fresnel lenses.

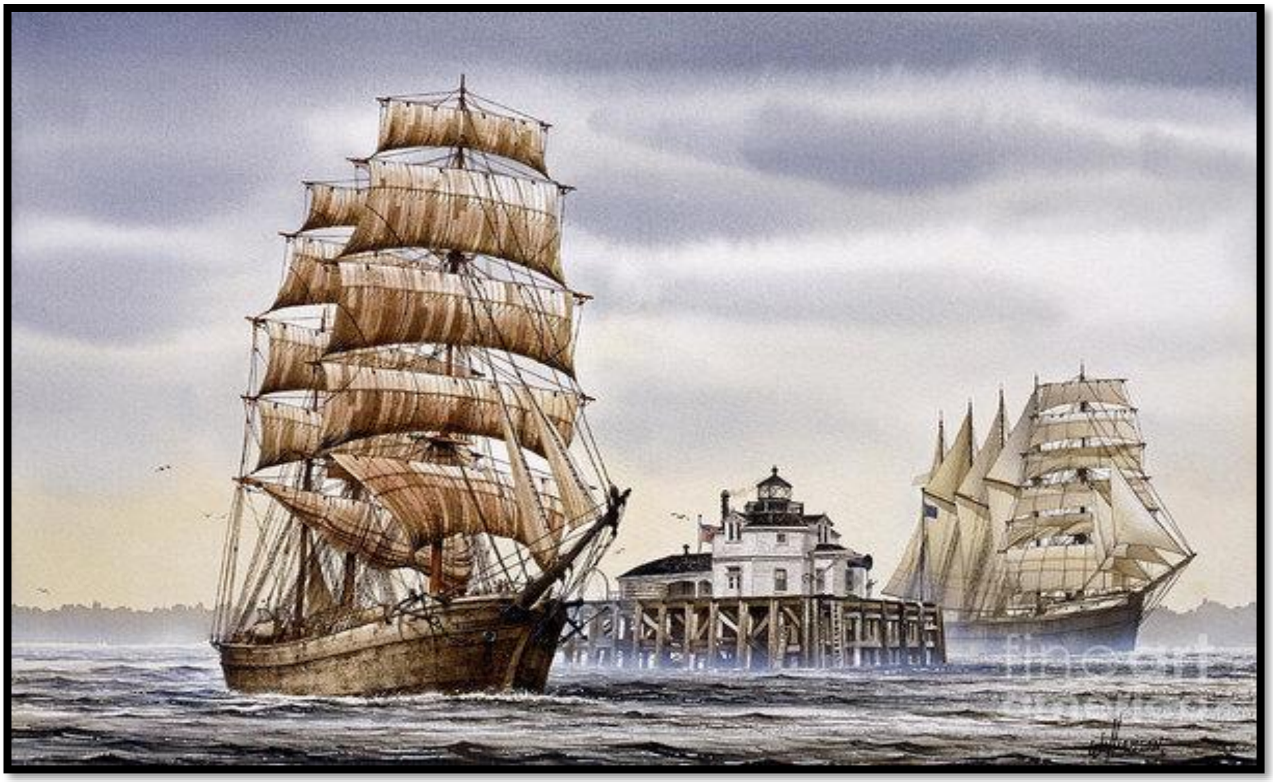
What is a lighthouse? It is nothing but a tower with a bright light at the top, located at an important or dangerous place regarding navigation (travel over water). The two main purposes of a lighthouse are to serve as a navigational aid and to warn boats of dangerous areas. It is like a traffic sign on the sea. Although we often think of a lighthouse as a tall, white conical tower, there are many, many variations of design. Depending on its location, it might be tall (where the land was very flat) or short and squat (where there was a high cliff or rocky coast). It could be square, octagonal (with eight sides), conical (like an ice cream cone upside down), cylindrical (like a very fat pipe), or even like a skeleton. You might find the lighthouse standing alone, attached to the building where the lighthouse keeper lives, or connected to the keeper's quarters by an enclosed walkway. Sometimes the lantern room is built into the roof of the keeper's house.
Location: They can be found in a variety of places, on rocky cliffs or sandy shoals on land, on a wave swept reef in the sea, and at entrances to harbors and bays. They serve to warn the sailor of dangerous reefs beneath the sea or perilous rocky coasts on land, and to guide ships into a safe harbor or back out to sea. So the message of the lighthouse might be - STAY AWAY, DANGER, BEWARE, or COME THIS WAY. Every lighthouse tells the mariner, "This is exactly where you are."

Universal: Each country, unless landlocked, has several coastlines used by ships from around the world. The USA for instance is bordered by the Atlantic Ocean in the East, in the West the Pacific Ocean, and in the South, the Gulf of Mexico. But we also have another very important area of coastline where the land meets the sea, the Great Lakes. All of these four areas bordering our country need and have lighthouses, as well as some of our more important navigable inland waterways.

Daymark and Night mark: Before they had all the sophisticated technology of today - loran, radar, sonar, on ship electronics, radio beacons, etc. - ships near shore in the daytime would use lighthouses as a landmark. This use gave them an additional name - a Daymark. Imagine that you are the captain of a ship sailing along the coast. You need some landmarks to help you find your position. When you look on shore, you see a tall red brick tower. Then you sail about forty miles down the coast and you see another round red brick tower -just like the first one. How would you know where you are?

A classic example given is the portion of the Virginia and North Carolina coast in the 1870's. To help the mariner determine his location the Lighthouse Board (which was in charge of lighthouses from 1852-1910) issued an order to have each lighthouse painted in different colors and/or designs. This is the best example of DAYMARKS we can see today.

Nighttime is the most dangerous time to navigate, and the main reason lighthouses exist. One cannot see colors or patterns at night in pitch darkness, cloudy nighty covering the moon or moonless nights -but definitely one can see lights. However, unless there was some way to make each light different, you could have the same problem. Early on, multiple lights (that is, two or three together) were built. Building double or triple lighthouses was one way to help the sailors at sea determine their location, but it was a very expensive way to do it. Mounting a group of lights on a rotating framework made it possible to produce a special signature (the first flashing characteristic) for each lighthouse, so they could be easily told apart. The invention of the Fresnel lens in 1822 was probably the most important discovery in lighting technology. As well as enabling man to produce an unlimited number of flashing combinations, it also intensified (brightened) the light so it was much more helpful to the mariner, and could be seen at greater distances. The Fresnel (pronounced "Frey Nel") lens can be compared to a huge lamp shade except that it is made of hundreds of pieces of beautiful, specially cut glass. It surrounds the lamp bulb, but differs from a lamp shade, which concentrates the light downward. This lens, due to its special design, and because it is made of glass, intensifies the glow from the light. It takes the rays of light which normally scatter in all directions and bends (refracts and reflects) them, focusing them into a single beam of light, which shines out in a specific direction. Fresnel lenses are of two types: Fixed - which shows a steady light all around the horizon and Revolving - which produces a flash or a characteristic. The number of flashes per minute depends on the number of flash panels and the speed at which the optic (lens) revolves. Different periods of darkness and light produce a unique flash pattern for each light. For example, a light can send out a flash every five seconds, or it might have a fifteen second period of darkness and a three second period of brightness, or any number of other combinations. The individual flashing pattern of each light is called its

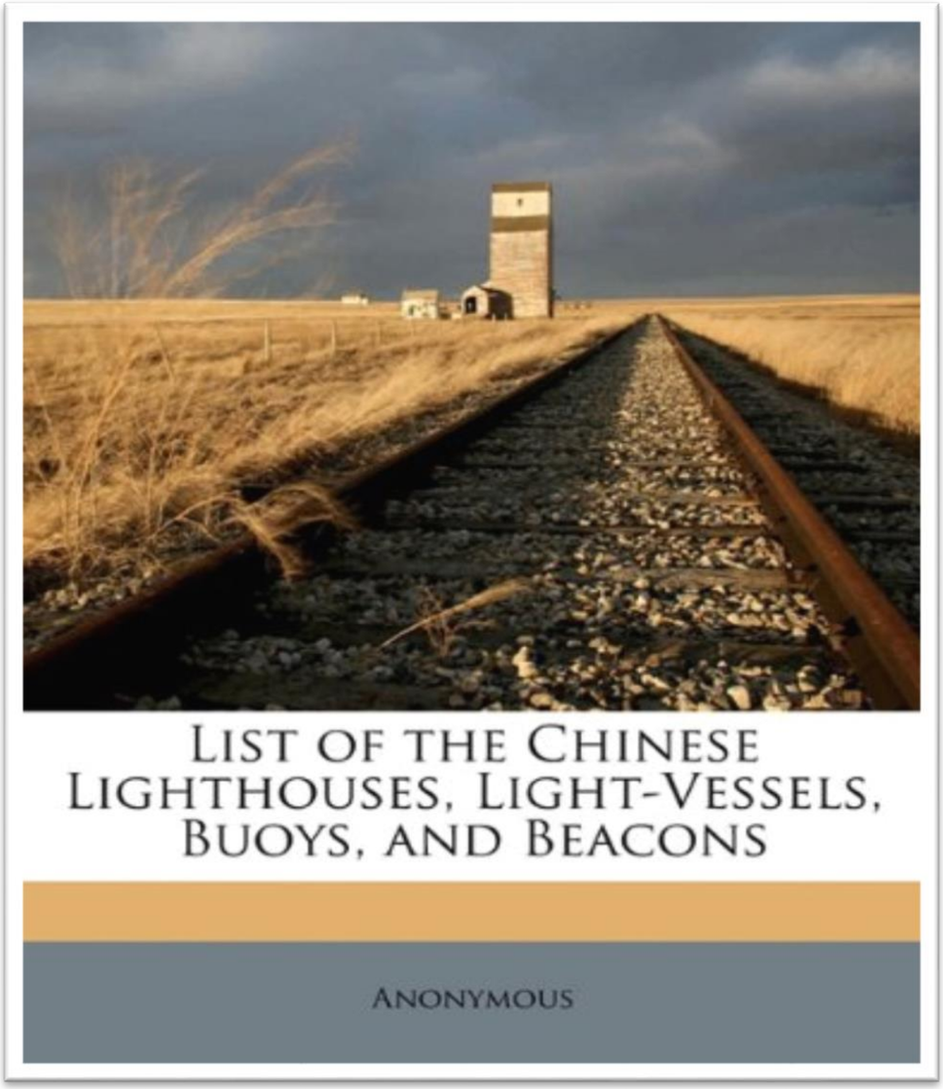


Characteristics: Mariners have to look at a light list or a maritime chart which tells what light flashes that particular pattern and what color the light is as well. Then they are able to determine their position at sea in relation to the land. Fresnel lenses come in seven commonly used sizes (called orders). The larger ones (1st order), used on major seacoasts, flash a more powerful beam which shines as far as twenty one miles out to sea. Sixth order lights, the smaller ones, are used in bays where they don't have to shine as far or as brightly. Most look like a beehive or barrel; some have bull's-eyes and can contain from two to twenty four different panels. Those with the fewest flash panels (two) are called clamshell or bivalve lens. A clockwork type mechanism (which had to be wound by hand every few hours before the advent of electricity) is used to make these revolving lenses rotate around the lamp itself to produce the flash. The movement of the lens is timed precisely so the bull's-eye panel will pass by when a flash is due. These lenses are really beautiful works of art; most contain hundreds of prisms - pieces of specially ground, cut and polished glass which, when arranged in a certain way, bend (reflect and refract) the light. Thus all the rays of the light are collected and redirected into a single pencil beam of light. This makes it much brighter and more effective. The lenses themselves can weigh as much as four tons. Another way to distinguish lights is through the use of color. Although most lights have a white lamp, some do use red and others green lights, as well as combinations of the colors.

Fog: What happens in fog when the light isn't visible? Have you ever been out in a car on a dark, stormy, very foggy night? You know how difficult it is to see other cars on the road. Now, picture yourself sailing along a black- looking sea in a thick pea soup fog with no stars shining or moonlight visible. The windshield wipers are working overtime, but the view of the light from the lighthouse is being blocked by the fog. In situations like this there is another method of notifying the mariner using sound. It is called a foghorn. The first one was used in 1719 at Boston light and it was, of all things, a cannon. Can you imagine being a lighthouse keeper and having to fire the cannon every hour when there was fog? During a long spell of fog you wouldn't get any sleep. Later they tried various other means of making a noise for warning. Fog bells were used as well as steam whistles and reed trumpets and sirens. The sounds they gave out were generally low pitched and very mournful - almost like a wail. Each one emitted a specific number of blasts every minute so it could be told apart from all others. Today, an automatic sensor which detects moisture in the air turns on the fog signals when needed. There are also soundless fog signals called radio beacons (an electronic device). These fog signals were not placed everywhere. Although some places experience no fog problems, fog warning devices are very necessary in New England, on the Pacific Coast, and in Alaska. What fuels were used to produce light? The main source of power for the light today is electricity, although in some places they use acetylene gas.

(C) WahooArt.com

For thousands of years before the electric lamp bulb was invented by Thomas Edison in 1879, different fuels were used to illuminate the lamps. First, it was wood and coal for fires, then bales of oakum and pitch, and rows of candles. Later lamps were lit using various fuels - sperm whale oil (produced by cooking the blubber of the whale), lard oil (from animal fat), kerosene (a fuel like gasoline with a petroleum base), etc. When they first designed a lighthouse with an enclosed lantern room it was possible to use candles for light. One lighthouse used 60 candles! Most used far fewer candles which were sometimes arranged in a circular candelabra or a chandelier with two tiers, or on a frame. Next came spider lamps which consisted of a shallow brass pan containing oil with either four, eight or more wicks usually arranged in a circle, but other shapes such as a rectangle were also used (since a spider has eight legs, the first one probably had eight wicks!).



LIST OF THE CHINESE LIGHTHOUSES, LIGHT-VESSELS, BUOYS, AND BEACONS

ANONYMOUS

Two very important discoveries occurred in the late 1700's. The parabolic reflector was a bowl-like device with a small oil lamp in the center. The light from the lamp was gathered and focused into a beam. This was similar to putting a mirror behind a flame. Thus the first really efficient lighthouse was created. Think of a flashlight which has a silver reflector behind the tiny bulb to increase the brightness of the light. It is based on the same principle. The invention of the hollow wick oil lamp (the Argand lamp) resulted in a light which was seven times brighter than a candle.

This lamp was used with various types of fuel inside the Fresnel lens until the electric light bulb was invented.

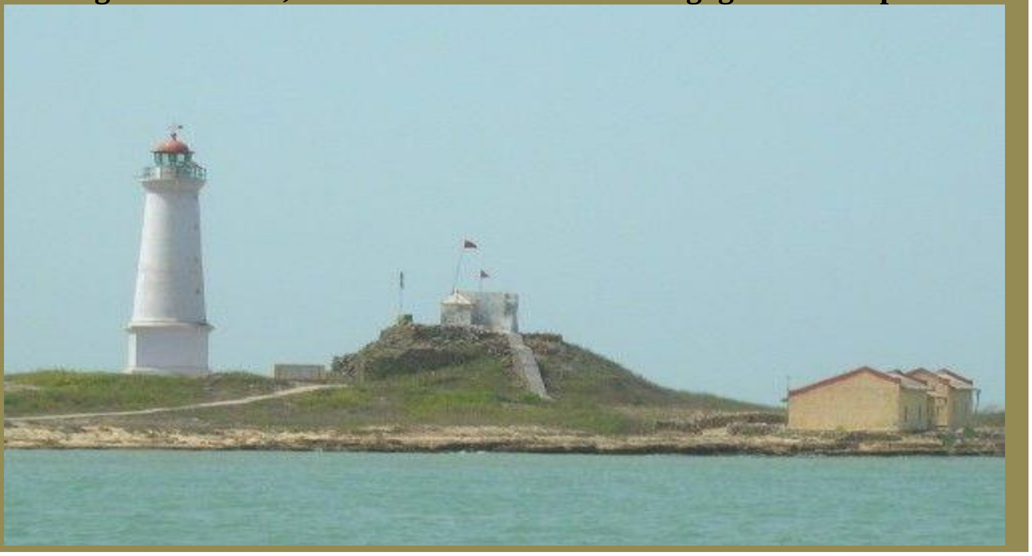
The first lighthouse ever to use electricity in the world was the Statue of Liberty in 1886. Yes, this special symbol of freedom was used as a lighthouse in harbor for the first fifteen years of her existence New York. When were the first lighthouses built in our country?” The first known lighthouse in India was at Puhar Port in Kaveripatnam, an ancient south Indian Port City. The famous Tamil writer Illango Adigal of 7th century AD in his book Silappadhikaram had explained in detail about the beautiful lighthouse in the Bay of Bengal coast and the numerous ships anchored at Puhar port, which was doing brisk business those days.

The excavations in the Indusvalley civilization had proved the existence of a well planned port at Flothal in the Northwest province of India in 3000 BC, and it is believed that lighthouses were built in India in the 3rd century BC itself by Emperor Asoka who was a contemporary of Ptolamy II, the Egyptian king who built the famous lighthouse of Alexandria. The oldest lighthouse tower still standing erect is at Mahabalipur, 65 KM south of Madras in south India.

Pallavas who encouraged sculptures during their reign built this beautiful rock sculptured bonfire lighthouse standing on tip of Olakkaneeswar Temple in the 8th century AD.

After the invasion of the Indian subcontinent by the Portuguese, Dutch and the English, the business through sea increased several folds and lighthouses were built all along the coastline of the Indian subcontinent and these lights were maintained by the local rulers and port authorities. When the number of lighthouses increased, it became essential to constitute an authority to control and maintain these lights. After detailed discussions and consultations, the decision to constitute a lighthouse department in British India (and the jurisdiction was from Aden to Rangoon) spread in the present nations of Iran, Pakistan, India, Bangladesh and Myanmar. The Lighthouse Bill was passed in 1927 and the Lighthouse Department constituted thereafter had the control of 32 lighthouses. When Independent India was formed in 1947, the number came down to 17 but merging of erstwhile princely states to Independent India, gave the control of 50 more lighthouses to the Lighthouse Department. Now after 55 years of Indian independence, the Lighthouse Department is maintaining 168 lighthouses, 1 lightship, 10 DGPS stations, 11 Radio beacons, 29 Racons and 6 Loran-C stations.

There are two lighthouses in Samiyani Islet, a green light in the north end and a white light in the Center. Except for the lighthouses, the other constructions available in the barren island of Samiyani are a small Temple of Hindu Goddess Samiyani Mata and a tomb of a Muslim saint. The first lighthouse with a 20m stone masonry tower and wick lamp was commissioned at Samiyani in the year of 1876. On September 20th, 2002, mechanized boats were arranged from the Okha passenger jetty to Samiyani Island to transport the local population for attending the function, and two hovercrafts were engaged to transport the guests of honor.



Samiyani is an islet at the end of a 1.5 KM long reef extended from Okha, in the mouth of Gulf of Kutch and it protects the ships anchored at Okha Port from the fury of nature. Picture above shows the holy sites of two religions guarding the lighthouse

The Governor General of British India gave approval to the Lighthouse Bill on September 21, 1927. To commemorate this, every year September 21st is celebrated as Lighthouse Day in India. On September 21st, the 75th year of the formation of the Indian Lighthouse Department, the Platinum Jubilee celebrations were conducted at Samiyani and Okha Lighthouse premises

In the USA on the other hand the need for lighthouses at the major ports was realized long ago to help guide ships into the harbors, to prevent them from crashing, and thereby losing their precious cargoes. So, the first lighthouses were built by the colonies (which were called states when we became the United States of America). In those days the ship owners had to pay a fee (toll) for the use of the lights which helped cover the costs of their construction and maintenance. Each ship which passed by a A - 8 lighthouse on its way into or out of a port paid a tax based on the weight of the cargo it was carrying. They paid a penny for each ton of goods on board ship. You have to remember that in those days a penny was worth a lot more than it is today. Once we gained our independence from Great Britain and the federal government took charge in 1789, this fee was eliminated. What is the difference between a lighthouse and a light station? A lighthouse is the tower itself containing the lantern room with the lamp which shines its light. A light station (which is usually onshore, but occasionally on offshore islands) is the property containing all of the outbuildings (as many as eight) of the "station", as well as the lighthouse tower itself. There were usually separate living quarters, depending on the number of lighthouse keepers and assistants living there. Besides these, there would probably be an oil (or fuel) house, a barn, a boat house, and a fogsignaling building. What duties did lighthouse keepers perform? Before the days of electricity, they had to light the lamp at sunset and extinguish it at sunrise. During an 8 hour watch at night they had to climb the stairs in the tower one to three times a night to check on the light and wind the weights that operated the clock. Some lighthouses have as many as two hundred steps! Keepers earned the name "wickie" because one of their chores was to trim the burned lamp wick, so it wouldn't smoke and dirty the lens. The brass in the building had to be shined, and all the windows cleaned. Often it took a whole day to clean and polish the lens alone. It was very important to keep both the lens and the lantern room windows clean so the light would not be diminished (lessened) in any way. A daily log had to be kept detailing everything from the weather to the amount of fuel consumed. Keepers also had to tend to the mechanism used to operate the fog signal. During the year many items had to be painted. Keepers and their families were kept very busy. What is the most important aspect of the lighthouse? Of course it is the light that shines out from the lantern room at the top which encloses and protects the lens. This lantern room is made of metal and glass which is divided into sections by pieces called astragals. Usually the astragals are vertical (up and down), but some are diagonal.

Redundancy: Today, all of the lighthouses in any country have been automated, with very few exceptions but they too will be converted to electricity. Many of the lighthouses are now no longer needed because of advances in technology, and they have been or are being turned over to various government agencies or non-profit local organizations to maintain and administer. It is important to keep them in good condition for future generations to learn about their place in the history of our country. They also need protection from vandalism and threats of erosion.

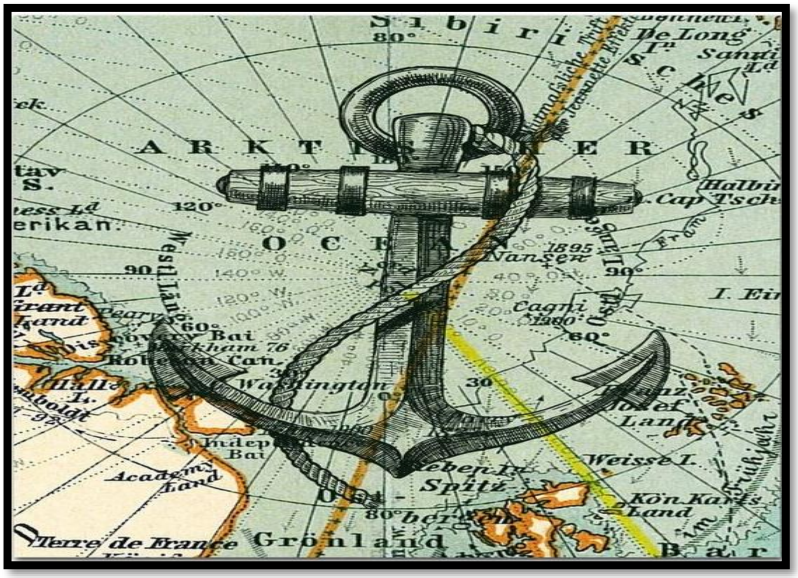
Tourism: And it is a special experience to be able to climb the stairs just as the keepers did and picture what life was like in times past. Why are people interested in lighthouses? The word "lighthouse" represents a variety of ideas and emotions...beauty, romance, isolation, fear, danger, security, sacrifice, home, etc. Lighthouses are usually stunning buildings in spectacular surroundings. Lighthouse stories epitomize some of the classic themes used by storytellers throughout history. The technology is interesting, the buildings are beautiful, the stories of the lighthouse keepers are fascinating. The keepers were a group of regular people who selflessly staffed isolated stations to help ensure the safety of others. All of these aspects combine to explain the growing popularity of lighthouses. It is important to save these buildings and their stories for the future.

In 1886, the Statue of Liberty became the first lighthouse powered by electricity, and served as a lighthouse in New York Harbor for 15 years. Most lighthouses had gone electric by the 1930s after access to electrical lines expanded. Electrical lines led to a series of inventions, including automated time clocks, devices to replace burnt-out light bulbs and improved radio communications technology, propelling lighthouses down the path toward automation.

Manned lighthouses had grown rare by the 1960s, when the Coast Guard implemented the Lighthouse Automation and Modernization Program. There were fewer than 60 manned lighthouses by the end of the decade. The modern lighthouse is a bare-bones structure comprised of an automated beacon atop a steel skeletal tower. Today, there is only one manned lighthouse in the United States.

The second purpose is to serve as a reference to mariners. An individual lighthouse distinguished itself with its day mark -- the color schemes and patterns on the tower -- and its light signature. For example, a lighthouse might emit two flashes every three seconds to distinguish it from a lighthouse that emits four flashes every three seconds. Even today, if the GPS goes on the fritz, crews reference light lists to plot a course -- those regional indices of lighthouses and their distinguishing traits.

At points before their automation in the 20th century, lighthouses had to accommodate cumbersome systems as well as a light-keeping staff to keep shining 24 hours a day. In addition to a lighthouse, a complete light station might include a fog signal building, a boathouse, living quarters for the keeper and his family and a separate oil house to cordon off the flammable agents that powered the lamps.



The Elements

"Finally the ship as a means of transport can be considered as an element in a geographically dispersed social, political and economic system. Warships impose political will by force; cargo vessels exist in a system of commerce; while passenger carrying vessels give clues to social classes and structure. Social status may also exist within the ship, for example, segregation between officers and seamen." Prior to being wrecked, the ship would have operated as an organised machine, and its crew, equipment, passengers and cargo need to be considered as a system. The material remains should provide clues to the functions of seaworthiness, navigation and propulsion as well as to ship-board life.

"When a ship is wrecked, it suffers many changes of state until the remains eventually reach equilibrium with their environment. Initially, the wrecking process changes it from the human organised form of a working vessel to an unstable state of structure and artefacts underwater. Natural forces act upon it during the wrecking process and continue to act until equilibrium is reached. Heavy items sink rapidly, lighter items may drift before sinking, while buoyant items may float away completely. This causes a filtering and scrambling of the material remains. The sudden arrival of a structure on the seabed will change the currents, often resulting in new scour and deposition patterns in the seabed."[3] Once underwater, chemical processes and the action of biological organisms will contribute to the disintegration. At any point in these processes, humans may have intervened, for example by salvaging items of value.

Therefore the **archaeology of shipwrecks** is the field of Archaeology specialized most commonly in the study and exploration of shipwrecks.Its techniques combine those of archaeology with those of diving to become Underwater archaeology. However, shipwrecks are discovered on what have become terrestrial sites.

It is necessary to understand the processes by which a wreck site is formed to take into account the distortions in the archaeological material caused by the filtering and scrambling of material remains that occurs during and after the wrecking process.

Goodwin Sands is a 10-mile (16 km) long sandbank at the southern end of the North Sea lying 6 miles (10 km) off the Deal coast in Kent, England. The area consists of a layer of approximately 25 m (82 ft) depth of fine sand resting on an Upper Chalk platform belonging to the same geological feature that incorporates the White Cliffs of Dover. The banks lie between 0.5 m (1 ft 8 in) above the low water mark to around 3 m (10 ft) below low water, except for one channel that drops to around 20 m (66 ft) below. Tides and currents are constantly shifting the shoals.

More than 2,000 ships are believed to have been wrecked upon the Goodwin Sands because they lie close to the major shipping lanes through the Straits of Dover. The few miles between the sands and the coast is also a safe anchorage used as a refuge from foul weather known as The Downs. Due to the dangers, the area – which also includes Brake Bank – is marked by numerous light vessels and buoys. Hidden just beneath the water's surface at high tide, the Sands are one of the most dangerous spots in the English Channel. In late November 1703, when southern Britain saw the worst natural disaster in its history, a massive cyclone now known as the Great Storm, more than 1,000 seamen died on the Goodwin Sands.

History: Notable shipwrecks include HMS Stirling Castle in 1703, VOC ship Rooswijk in 1740, the SS Montrose in 1914, and the South Goodwin Lightship, which broke free from its anchor moorings during a storm in 1954. Several naval battles have been fought nearby, including the Battle of Goodwin Sands in 1652 and the Battle of Dover Strait in 1917.

When hovercraft ran from Pegwell Bay, Ramsgate, they used to make occasional trips over the Sands, where boats could not safely go.

The dangers posed to shipping by the Goodwin Sands have long been recognised and the earliest record of a warning light being used on the Foreland relates to a Brother Nicholas de Legh, who hung a white light from cliffs near St Margaret-at-Cliffe a little to the north.[3] 17th and 18th century

South Foreland as seen from the sea.

The first pair of lighthouses at South Foreland was built in 1635 by Sir John Meldrum.[3] (He also built the first North Foreland Lighthouse, 15 miles to the north, the following year.) The light at this time was provided by an open fire burning in a brazier on the roof. Responsibility for the lighthouses (and rights to the associated light dues) were passed to a Robert Osboldston in 1643, and then in 1715 to Greenwich Hospital.In 1730 one William Knott began a period of service as lighthouse keeper at the Lower Lighthouse. Over the next 175 years five generations of the Knott family would serve as lighthouse keepers at South Foreland, making them 'probably the longest dynasty of keepers anywhere in the world'.

In 1793 the Upper Lighthouse was rebuilt with an oil lamp and parabolic reflectors in place of the brazier; the Lower Lighthouse was similarly rebuilt two years later (as a two-storey building, whereas the Upper Lighthouse was three storeys). John Yenn was the architect.[3]

19th century

South Foreland Lower Lighthouse in 2012

In 1832 the Corporation of Trinity House purchased the lease for the South Foreland lights from Greenwich Hospital. Ten years later the Upper Lighthouse was heightened and refurbished with a multi-wick oil lamp and a first-order fixed dioptric optic, manufactured by Henry-Lepaute of Paris. Then, the Lower Lighthouse was entirely rebuilt, in 1846, and provided with a fixed array of fifteen Argand lamps and reflectors.[6] The architect and engineer for both these projects was James Walker.[7] At the same time new accommodation for the keepers was built alongside each tower.

In the 1850s Michael Faraday, scientific adviser to Trinity House, was exploring the feasibility of electric light being used in lighthouses; several different solutions were proposed. In 1857 Frederick Hale Holmes demonstrated his magneto-electric apparatus to Faraday, proposing its use in conjunction with carbon arc lamps. The initial trial was conducted at South Foreland Upper Light, which thus became the first lighthouse to use electric light.[8] The South Foreland trial began in December 1858 and continued until early 1860; afterwards Holmes's

equipment was installed on a more permanent basis in Dungeness Lighthouse, in 1862. (Meanwhile, at South Foreland that year, experimental use was being made of a Drummond light at the high lighthouse; however, 'the results were not satisfactory' with regard to its potential for lighthouse illumination.. In 1871 Souter Lighthouse became the first to be designed and built for electric operations**.**[1]

A Geological Study of the Titanic Shipwreck Site

After the R.M.S. Titanic struck an iceberg on Sunday, 14 April 1912, its further fate remained a mystery for over seventy years. At the time survivor testimonies claiming that the ship broke in half were dismissed as inaccurate. When the wreck was discovered in September 1985 almost 370 miles south-southeast off the coast of Newfoundland, it was indeed confirmed that the ship broke into two large pieces and into many smaller pieces creating a debris field approximately 15 square miles in size. The ship's bow is still mostly intact, even if most structures on deck collapsed when the sinking Titanic hit the seafloor. The ship's stern was crushed by the impact and water pressure. A large debris field, with hundreds of thousands of items, from machinery to personal items of the passengers, is scattered between the two parts of the ship.

The remains of Titanic rest at the end of Cameron Canyon (named not after the famous filmmaker James, but after Canadian scientific researcher Harky Cameron) descending from the Newfoundland Ridge to an abyssal plain about 2.5 miles below the ocean surface. The canyon floor is covered by sediment debris and slumps transitioning into the Titanic Sediment Wave Field, a large muddy plain, characterized by dunes, sand ribbons and sheets, formed by strong underwater currents moving through the area. These currents are probably also the reason why the debris from the sinking ship is scattered over such a large area.

Five years in the making, Titanic sank in less than three hours and will probably not last until the end of this century. Apart from the damage done by the sinking, also time is consuming the Titanic. According to some research, the wreckage will eventually be buried in about fifty years by sediments. Also, microorganisms living in the deep sea contribute to the wreck's decay.

During the first visit of the wreck with a submarine in 1986, researchers discovered that various bacteria and fungi colonized the wreck. One type of bacteria was even an unknown species, appropriately named *Halomonos titanicae* in 2010. The microorganisms produce energy to sustain their metabolism by oxidizing the iron parts of the ship. The microbial metabolism forms a thick layer of rust covering the entire wreck, forming even stalactites (called rusticles) on windows and fissures of the hull. Every day the microorganisms consume almost 100 pounds of iron. The upper ship's decks are made from thin steel plates and will probably last for another ten to fifteen years. The ship's hull is made of thick plates, and even if not strong enough to resist the iceberg that fateful night, the steel will resist for some decades on the bottom of the ocean. However, in the end, the weakened hull will collapse completely and be buried by sediments, transported by the currents.

During an expedition in 2004, Robert Ballard, found plastic cups from passing ships and iron chains or ballast bags of submarines visiting the site. The visitors heavy vehicles also damaged the wreck. Fissures are quickly colonized by the corrosive microorganisms. Yellow stains of decomposing iron document this process on the upper decks and the bow. Also, human activity on the sea surface has impacts on the Titanic. Unsustainable fishing along the Grand Banks of Newfoundland has significantly reduced the local fish population in the last decades. A smaller population consumes less plankton in the upper layers of the ocean and more organic matter sinks to the bottom of the sea. Here, the surplus of nutrients causes a bloom in the microbial deep-sea community covering the wreck. As the microbes multiply and feed on the wreck, it will accelerate the slow, but incessant, decay of the Titanic.

Some traces of the disaster will always remain on the bottom of the sea. In 1991 Cameron Canyon was formally renamed to Titanic Canyon. Also, a number of nearby seamounts were named after the vessels involved in the disaster. For example, *Carpathia* honors the first ship to arrive at the site of the disaster in 1912 and saving 743 surviving passengers.

David Bressan https://www.forbes.com/sites/davidbressan/2019/04/14/a-geological-study-of-the-titanic-shipwreck-site/#396043e6431a

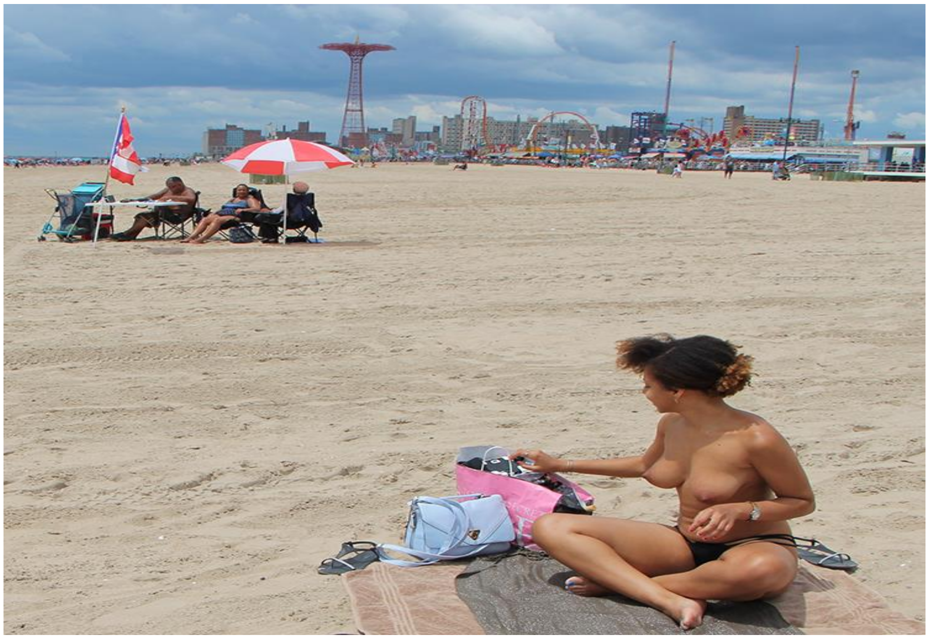
The History and Technology of Lighthouses

No two lighthouses have been built the same. Early lighthouses used whatever materials were available locally: wood, brick, stone, concrete, reinforced steel and cast iron. Some lighthouses are placed onshore overlooking the water, while some are built offshore on reefs or patches of rocks. Even the height of the tower changes from one lighthouse to the next depending on the view from the water. A lighthouse overlooking a 100-foot (30.48 meter) cliff, for example, wouldn't need to be built as tall as one positioned closer to sea level.

There are regional similarities in construction, however: Lighthouses built in the Outer Banks of North Carolina are built in intervals so that if a ship maneuvering down the coast lost sight of one lighthouse, it would find the glow of the next one

Lighthouses have been around since ancient Egypt. The Tower of Hercules, built by the Romans in northern Spain during the first century A.D., remains the oldest functioning lighthouse in the world And as maritime trade expanded, so did the presence of lighthouses around the world, from China to Indonesia to Africa to Estonia. Famously, the Stevensons, a Scottish family of lighthouse engineers that counted author Robert Louis Stevenson among its progeny, built 97 lighthouses along the Scottish coastline and elsewhere.

Lighthouses first appeared in New England in 1716. In 1789, Congress created the U.S. Lighthouse Establishment to bring lighthouses under federal control. After first earning a second-rate reputation for the poor quality of its lighthouses, the United States became home to more than 1,000 lighthouses by 1900. And with more than 120 lighthouses, the state of Michigan possesses more lighthouses than any other state.



Coney Island Nudist Beach

Rogue Waves: To understand the effects of rogue or freak waves on ships at sea, it is vital to first develop an understanding of rogue waves in itself, the occurrence of such a phenomenon and the reason behind such an occurrence.

The occurrence of sea waves is an uncertain phenomenon. That is, if you consider a certain area of the sea surface, the waves passing through that area would definitely be periodic in nature, but the parameter of each wave (amplitude, time period, frequency, wave height and wavelength) will vary at a rate that cannot be determined to any exact measure. o understand that with an example, let us suppose that a wave of height 10 meters passes through a given area on the sea surface at this instance. Then one cannot be sure if the next wave passing through the same area on the sea surface will have the same height. This natural uncertainty in the nature of sea surface waves makes it important for us to study sea waves in a probabilistic and statistical approach, rather than a deterministic approach.

o, we plot the probability of the occurrence of a particular wave height on what is called a histogram. The horizontal axis representing increasing height of wave and the vertical axis representing the probability of occurrence of a wave of the corresponding height.

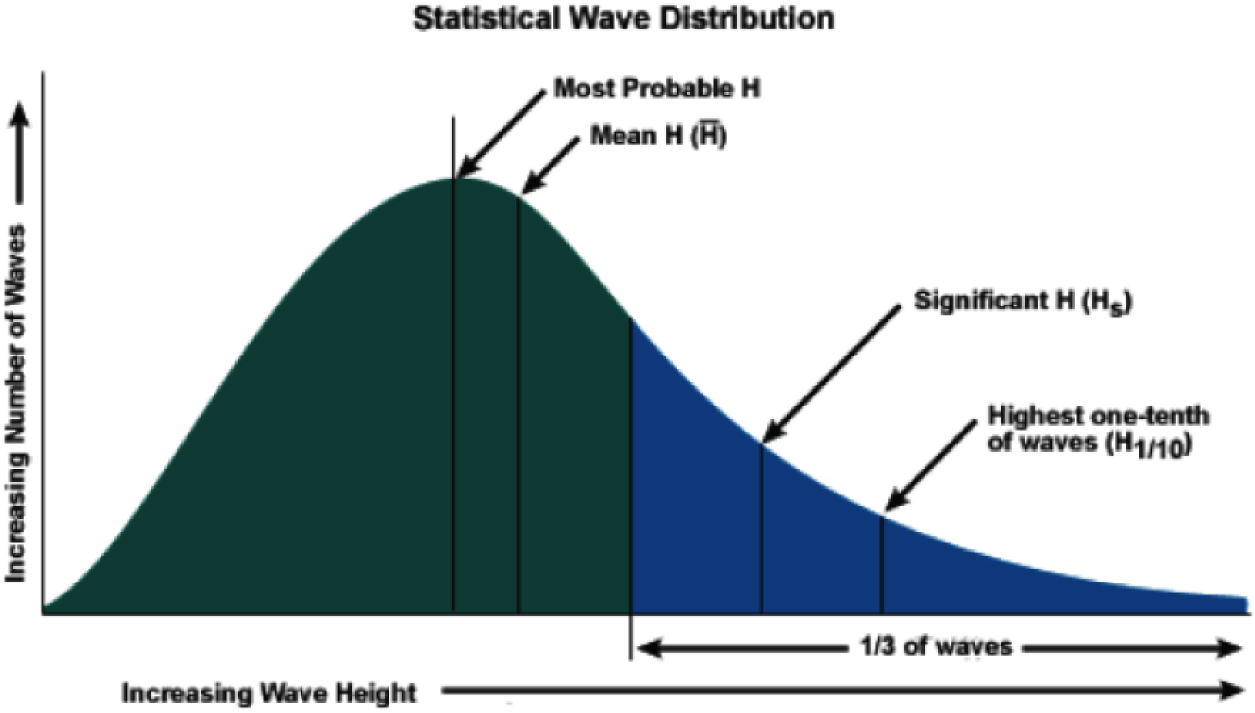


Figure 1: Sea wave spectrum

- he probability of a zero wave height is zero (which is evident, since there is no sea without a wave)
- The probability of occurrence of extremely high waves is also tending to zero
- The wave height corresponding to the maximum probability is somewhere higher than zero, in the moderate height region. These are the wave heights we see daily in a normal sea. The height corresponding to the maximum probability is maximum probable height
- The average of highest one-third of waves is the significant wave height (Hs). This is very important, as in, it is considered the reference point of designating a wave as a freak wave
- Any wave that has a height more than that of significant height is called a rogue wave. So, as clearly evident, the probability of occurrence of a freak wave is lower, but due to its height, the energy stored in one freak wave can be high enough to cause damage to ships

To know what effects rogue waves have on ships, we need to know the motion of a ship in a wave. When a ship operates in head seas, it experiences pitching coupled with heaving motions. The more the amplitude of the encountering wave, higher is the pitching and heaving amplitude.
xtreme combined motions of pitching and heaving in ships result in the forward part of the ship plunging into the sea surface after it encounters a wave. So, in some cases, when the sea state is high, there is a probability of increased height of waves that a ship may encounter. Sometimes, these waves may be higher than that corresponding to significant wave height, which is called freak waves or rogue waves.

The problem with such waves, is that they cannot be predicted, owing to the natural uncertainty of sea waves.Rogue waves (also known as freak waves, monster waves, episodic waves, killer waves, extreme waves, and abnormal waves) are unusually large, unexpected and suddenly appearing surface waves that can be extremely dangerous, even to large ships such as ocean liners. The following are the effects on ship that occurs because of encountering rogue waves at sea:

Bow Slamming:

When a ship encounters high waves (especially in head seas), high amplitude pitching and heaving combined, produces an effect that sends the bow out of the water. As the wave passes aftward, the bow falls onto the surface (or slams the surface), with high acceleration, resulting in tremendous slamming forces in the forward structure of the ship.

Image for representation purpose only

Formation and Propagation of Cracks:

Due to high slamming and pounding forces in the forward structure, the hull at the bow section is often prone to cracks that can propagate over the entire depth of the bow section.

Buckling of plates:

The shell plates at the bow and the bottom plating upto 25 percent of the ship's length aft of the forward perpendicular is subject to effects of slamming which result in buckling of these plates. Especially the bottom plating in the forward region, because in most lading cases, the ship is in hogging condition, which maintains the bottom shell in a state of compression. Major augment of stresses in the bottom plating therefore result in exceeding the buckling stress of the material, which may be much lower than the ultimate tensile stress.

Ultimate Failure

When forward structures have been subjected to large number of cycles of freak waves or slamming forces over a longer period of time, the structure undergoes fatigue. If scantling and structural surveys are not carried out regularly, then ultimate failure, leading to complete rupture of bow sections is not an impossibility when encountered with freak waves.

So designers have over the years, developed methods to combat freak waves by incorporating various factors of safety in structural design. Broadly, we will discuss them under the following distinctions:

Inclusion in Structural Formulae:

When the scantlings of a ship are calculated in preliminary design phase, designers use empirical formulae suggested and tested by classification societies. These formulae have been developed over extensive observation and analyses of statistical data of stressed that ships are subjected to at sea, and accordingly, factor of safety are considered in determing the scantlings, so as to prevent failure due to waves that are above the significant height.

Additional Strengthening against Slamming:

The hull girder is additionally strengthened at the bow. Some of the additional structures that are included are discussed below:

- Panting stringers that run longitudinally, are welded to the sideshell forward of the collision bulkhead. The height between subsequent stringer is usually 2 to 2.5 meters
- Panting Beams run transversely inside the deck shell, joining the panting stringer to the centreline wash bulkhead
- Angled pillars are used to support the panting beams at the centreline
- Panting web sections or perforated flats are used after between every one or two panting stringers. The side frames are end connected to these and the panting stringers via tripping brackets to ensure smooth stress flow
- Plate floors are used at every frame space ahead of the collision bulkhead

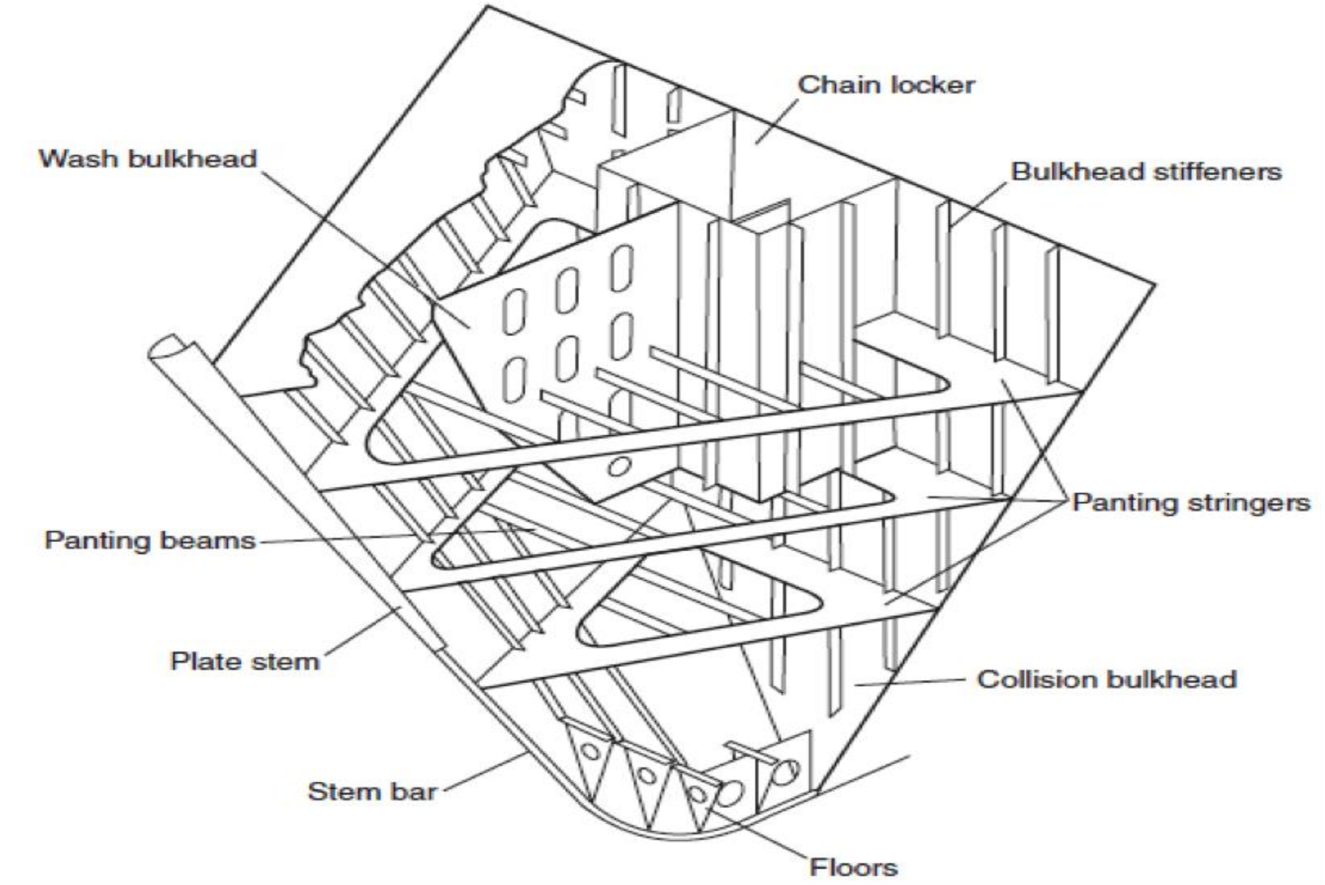
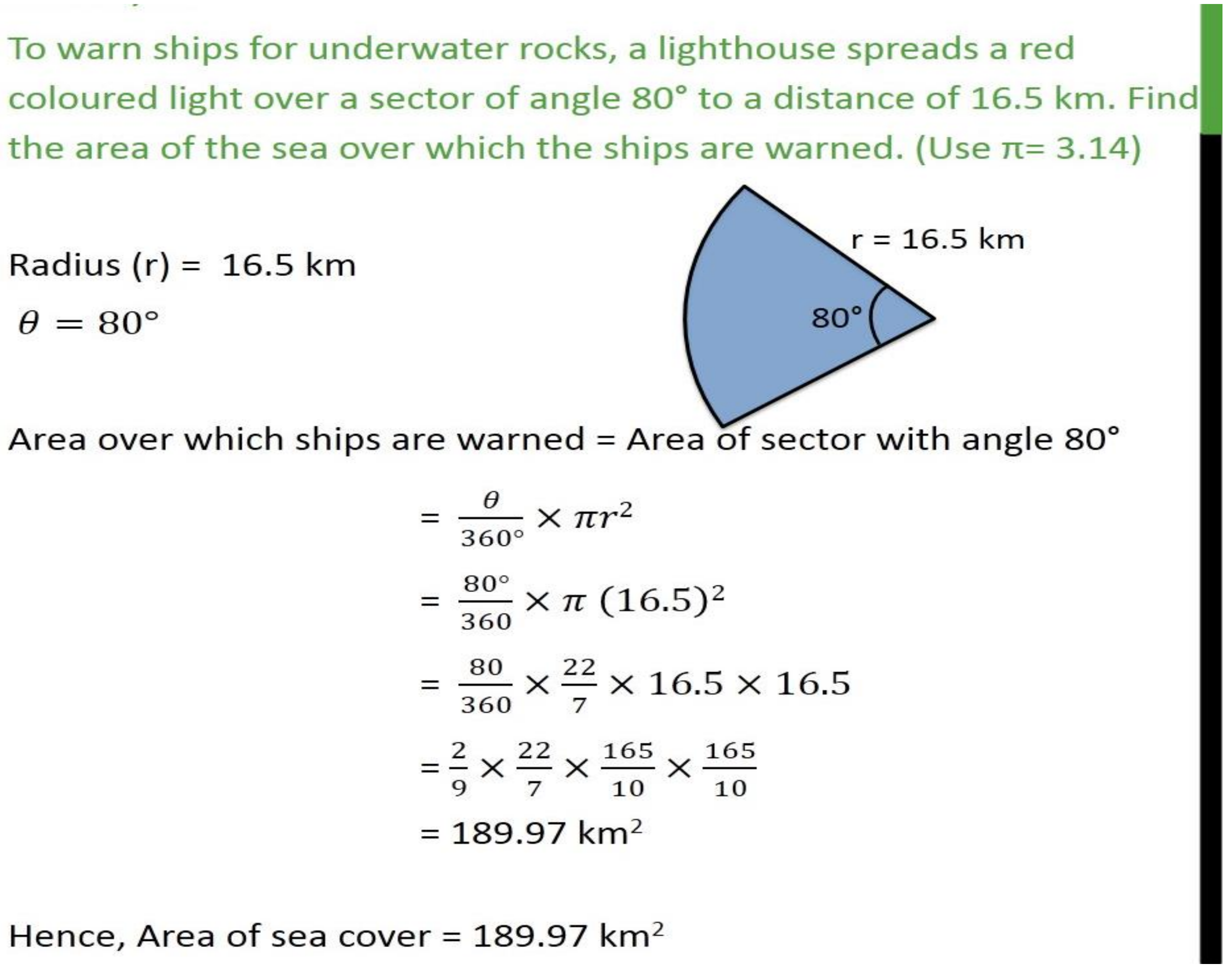


Figure 2: Additional strengthening of forward structure

Navigational Measures Taken On-Board:

Navigational measures are also taken on board a ship, to combat rogue waves, especially in high sea states. Remember the initial paragraphs of this article where we discussed about pitching and heaving motions induced onto a ship? The idea of navigational measures is just to reduce the pitching amplitudes.

The pitching amplitudes depend on the encountering angle and the encounter frequency. The encounter frequency is changed by changing the speed of the ship, and the encounter angle is altered by changing the heading of the ship. Though the latter may not always be feasible on fixed routes, the former is mostly used to reduce unwanted motions on the higher side.[2]



To warn ships for underwater rocks, a lighthouse spreads a red coloured light over a sector of angle 80° to a distance of 16.5 km. Find the area of the sea over which the ships are warned. (Use $\pi = 3.14$)

Radius (r) = 16.5 km

$\theta = 80°$

Area over which ships are warned = Area of sector with angle 80°

$$= \frac{\theta}{360°} \times \pi r^2$$

$$= \frac{80°}{360} \times \pi\ (16.5)^2$$

$$= \frac{80}{360} \times \frac{22}{7} \times 16.5 \times 16.5$$

$$= \frac{2}{9} \times \frac{22}{7} \times \frac{165}{10} \times \frac{165}{10}$$

$$= 189.97\ \text{km}^2$$

Hence, Area of sea cover = $189.97\ \text{km}^2$

Burhanuddin Dasgupta,2019

The Global Positioning System (GPS) has changed the way the world operates. This is especially true for marine operations, including search and rescue. GPS provides the fastest and most accurate method for mariners to navigate, measure speed, and determine location. This enables increased levels of safety and efficiency for mariners worldwide.

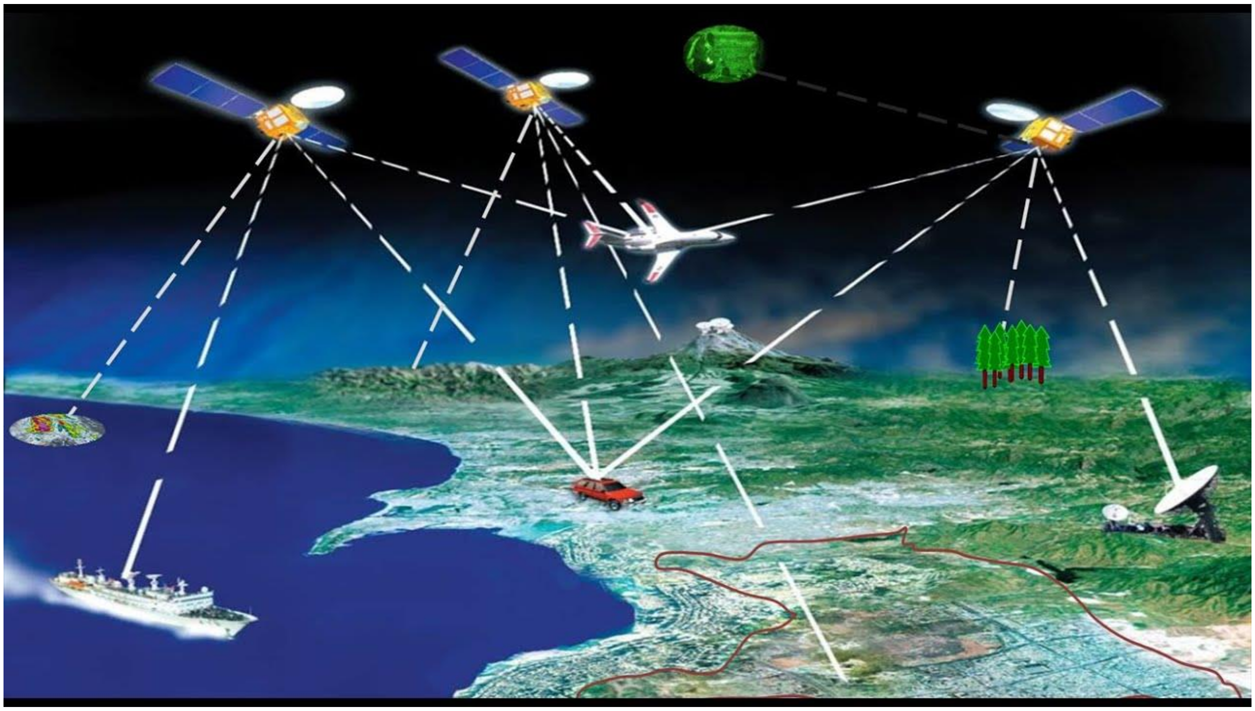
It is important in marine navigation for the ship's officer to know the vessel's position while in open sea and also in congested harbors and waterways. While at sea, accurate position, speed, and heading are needed to ensure the vessel reaches its destination in the safest, most economical and timely fashion that conditions will permit. The need for accurate position information becomes even more critical as the vessel departs from or arrives in port. Vessel traffic and other waterway hazards make maneuvering more difficult, and the risk of accidents becomes greater.

Mariners and oceanographers are increasingly using GPS data for underwater surveying, buoy placement, and navigational hazard location and mapping. Commercial fishing fleets use GPS to navigate to optimum fishing locations, track fish migrations, and ensure compliance with regulations.

An enhancement to the basic GPS signal known as Differential GPS (DGPS) provides much higher precision and increased safety in its coverage areas for maritime operations. Many nations use DGPS for operations such as buoy positioning, sweeping, and dredging. This enhancement improves harbor navigation.

Governments and industrial organizations around the world are working together to develop performance standards for Electronic Chart Display and Information Systems, which use GPS and/or DGPS for positioning information. These systems are revolutionizing marine navigation and are leading to the replacement of paper nautical charts. With DGPS, position and radar information can be integrated and displayed on an electronic chart, forming the basis of the Integrated Bridge System which is being installed on commercial vessels of all types.

GPS is playing an increasingly important role in the management of maritime port facilities. GPS technology, coupled with geographic information system (GIS) software, is key to the efficient management and operation of automated container placement in the world's largest port facilities. GPS facilitates the automation of the pick-up, transfer, and placement process of containers by tracking them from port entry to exit. With millions of container shipments being placed in port terminals annually, GPS has greatly reduced the number of lost or misdirected containers and lowered associated operation costs.



GPS information is embedded within a system known as the Automatic Identification System (AIS) transmission. The AIS, which is endorsed by the International Maritime Organization, is used for vessel traffic control around busy seaways. This service is not only vital for navigation, but is increasingly used to bolster the security of ports and waterways by providing governments with greater situational awareness of commercial vessels and their cargo.

AIS uses a transponder system that operates in the VHF maritime band and is capable of communicating ship to ship as well as ship to shore, transmitting information relating to ship identification, geographic location, vessel type, and cargo information -- all on a real-time, wholly automated basis. Because the ship's GPS position is embedded in these transmissions, all essential information about vessel movements and contents can be uploaded automatically to electronic charts. The safety and security of vessels using this system is significantly enhanced.

Finally, with the modernization of GPS, mariners can look forward to even better service. In addition to the current GPS civilian service, additional additional civilian signals are also implemented bringing inceased accuracy, more availability, and better integrity for all users.

Rogue wave

CHAPTER II

Lighthouse Organization and Structure

Basic Principles of Lighthouse Design and Location

Lighthouses may be broadly defined under two heads: wave-swept and land structures. Although the latter may frequently be found in exposed locations, in general the wave-swept tower offers the greatest challenge to designer and builder alike. There are four kinds of construction used in wave-swept towers at present:

(1) masonry and concrete,
(2) cast-iron plated,
(3) caisson foundation and
(4) openwork steel.

(1) Masonry and concrete construction is preferred at sites where stone or brick is costly to transport. The openwork steel tower is resorted to on shoals, coral reefs or sandbanks in which a secure foundation is to be had only by means of steel piles driven deep where excavation is impractical. Likewise, the caisson foundation often is recommended at such locations.[1] Figure 2 illustrates basic types of construction currently in use.

Lighthouses may also be functionally categorized under four general heads:

(1) landfall lights,
(2) major coastal lights,
(3) secondary coastal lights and
(4) harbour lights.

Landfall lighthouses are located on shipping approaches generally well offshore to serve as the first landfall for inbound shipping and to provide a first bearing for outbound shipping. As one would suppose, landfall lighthouses are equipped with the most powerful lights available. Examples of several well-known landfall lighthouses are Bishop's Rock off the Scilly Isles (the first sight of the approaching English coast on a course for the Channel), and nearer home, Cape Race and Belle Isle, from which eastbound shipping out of the St. Lawrence takes its departure.

Next in importance are the major coastal lights on the approaches to major ports or at the mouths of principal rivers. The Sambro Island lighthouse on the outer approaches to the port of Halifax and the oldest surviving lighthouse in Canada is an example in this category, as is Prince Shoal at the confluence of the Saguenay and St. Lawrence rivers. These two are fitted with powerful lights, although generally not to the same extent as the landfall lights. Secondary coastal and harbour installations exhibit lights of decreasing power and intensity; the latter, many of which may aptly be described as shaped like a pepper-shaker 10 or 15 feet in height, are often to be found at the head of piers or jetties.

Wave-swept lighthouse towers are usually of tapering circular design and are frequently set upon square foundations. Land-based lighthouses, by contrast, come in all shapes and sizes. Briefly they may be broken down into three broad types:

(1) towers solely,
(2) towers with attached dwellings and

houses with short towers, cupolas on the roof, or simply exhibiting the light from a window. Simple mast and pole lights are frequently seen on inland waterways other than those of such expanse as the Great Lakes. Towers are in a variety of shapes, circular, hexagonal and octagonal being the most common.

The range of a light; that is, the distance at which it can be seen in clear weather, is computed in nautical miles and is dependent on two factors; the height of the light above the water, governing what is termed its "geographic range," and the intensity of the light computed in candela (an internationally recognized unit of luminous intensity equivalent to a British standard candle), called its "luminous range." In the case of major lights of high intensity the range is limited only by the curvature of the earth—hence range varies directly with the elevation of the light. Atmospheric conditions such as fog, rain, snow or haze greatly reduce the range of all lights. Landfall lights are installed in towers up to 200 feet in height (often, though not invariably, the distance between high water and the focal plane of the light) with ranges of from 20 to as high as 25 nautical miles. Major coastal lights rarely exceed 150 feet.

Site is determined by its location. In general, tall towers are called for on low-lying shores or offshore rocks in order to gain the maximum range. On the other hand, lighthouses built on lofty promontories often call for squat towers, for if at a high elevation the light might too frequently be obscured by fog.

In choosing a lighthouse site an area subject to rapid coastal erosion should be avoided. Many a sturdily built lighthouse has been undermined by this process, necessitating removal to a safer location. Sable Island, with the unenviable title "the graveyard of the Atlantic," is a notorious example of the effect of coastal erosion, and another is Long Point on Lake Erie. The opposite phenomenon is coastal accretion, brought about by offshore currents or river estuaries dumping deposits in such amounts that the shoreline advances, thereby reducing a lighthouse's effectiveness.

Warning or encouragement: Another basic factor fundamental to the very purpose of a lighthouse was under debate in the early 19th century: Should a light serve to warn the mariner to keep well clear or encourage him to approach the location? A case in point again is Sable

Island. on which many a ship had foundered. As early as 1801, two lighthouses were recommended for this location, one at either end of the treacherous crescent-shaped isle, to be located as near the hazardous sandbars as possible. Nothing was done, however, other than the establishment of a rescue station. More than 30 years later, Francis (later Sir Francis) Beaufort, a celebrated naval hydrographer, condemned the project in his "Report on the several documents relating to the Lighthouses of the British Colonies in North America."

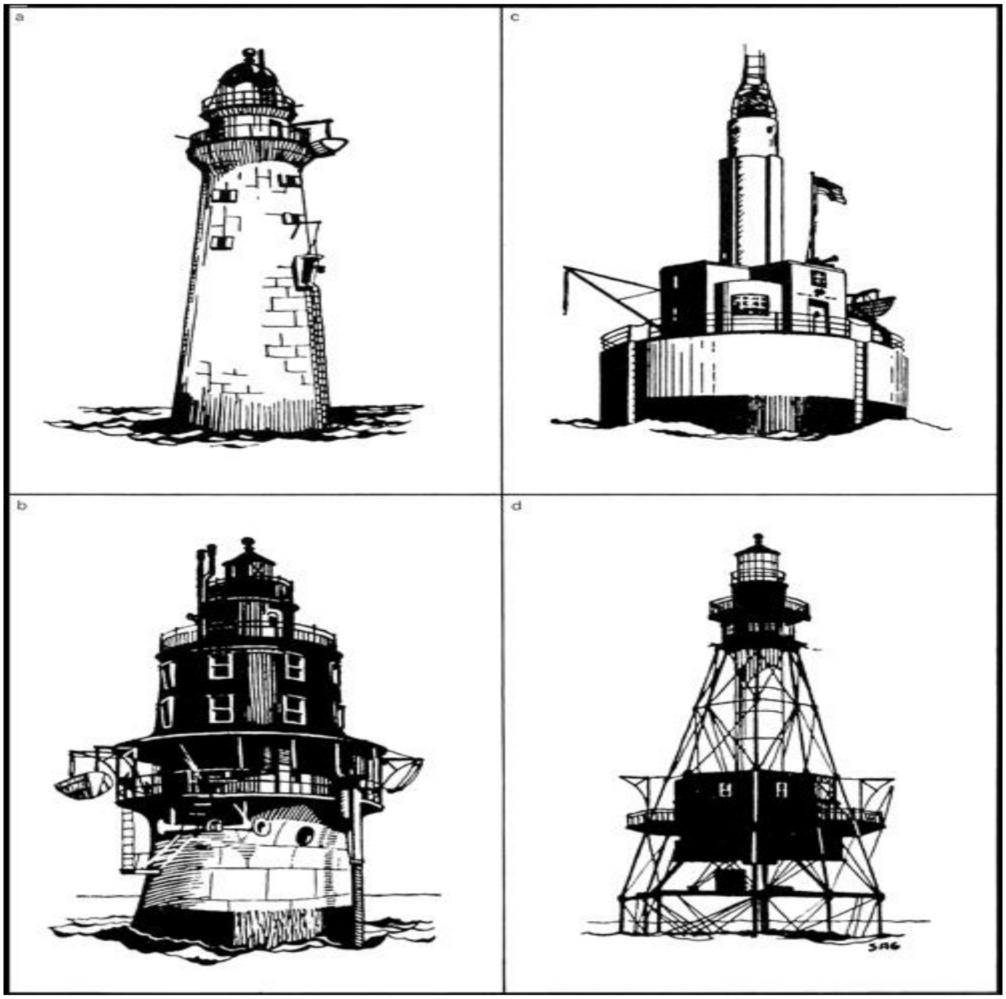
Nothing however could be more mischievous than placing there a light, though more than once recommended, it could scarcely be seen further than the shoals extend and could therefore always act as an enticement into danger. Another 38 years were to pass before the Department of Marine took the long-deferred project in hand and put the first pair of lighthouses in service in 1873. By that time, lights of such sufficient power were available that Francis Beaufort's objections were no longer tenable. Today lights serve both functions, depending on the location and hazards involved.

British Structural Design

The 18th century is noteworthy for the remarkable progress made in lighthouse construction and the beginnings of greatly improved lighting apparatus. Nowhere was this more apparent than in the British Isles, France and Sweden.

English architects pioneered the challenging design and construction of the first wave-swept towers, structures exposed, generally on rocks offshore, to the full onslaught of the sea. The first of these was the Eddystone light, 14 miles off Plymouth and open to the broad Atlantic. Henry Winstanley built the first Eddystone lighthouse, an elaborate tower in the Baroque tradition featuring galleries and projections. Completed in 1697, it was swept away by an unprecedentedly fierce storm on 26 November 1703. John Rudyerd, a silk mercer of London, assisted by two expert shipwrights completed the second lighthouse on the Eddystone Rocks in 1709. Although sturdily built of bolted and clamped oak timbers, this second structure fell victim to fire in 1775. The third lighthouse, built by John Smeaton between 1756 and 1759, subsequently was condemned due to subsidence of its foundation. The fourth and present Eddystone lighthouse, 133 feet in height, was completed by J. N. Douglass in 1882.

The most difficult project of all fell to a Scottish engineer, R. Stevenson, grandfather of the talented novelist and poet Robert Louis Stevenson. The construction site chosen for the Bell Rock lighthouse consisted of rocks 12 miles off the east coast of Scotland. The site was a peculiarly hazardous one because the foundation work was below high water. This well-known offshore light was completed in 1811. Yet another notable achievement was the building of the Skerryvore lighthouse off the Isle of Tiree, on the mountainous and irregular west coast of Scotland. The Skerryvore light, 158 feet in height, was completed in 1844. These exposed towers required a high measure of skilled design on the part of the engineer or architect, implemented by rugged masonry.[5]



2 Drawings of typical lighthouse structures: *a,* masonry tower; *b,* cylindrical tower on square house on round base; *c,* round caisson structure; *d,* skeleton iron tower. *(U.S. Coast Guard* *publication.)*

As steam replaced sail on the high seas during the rapidly industrializing 19th century, many waveswept lighthouses were built at exposed sites in various parts of the world, Horsburgh, Singapore in 1851: Minot Ledge, Massachusetts in 1860; Alguada Reef, Andaman Sea in 1865, and Great Basses, Ceylon in 1873 are but a few.

Canadian Tower Construction

Although the two earliest Canadian lighthouses, Louisbourg and Sambro Island, were very solidly built masonry structures, this was not to be the invariable pattern for the future. The British North American colonies were bound by the limitations of a more stringent purse than either the United States or Great Britain. In the case, for instance, of the two St. Paul Island lighthouses built in 1831 and 1839, the Elder Brethren of Trinity House in London strongly recommended stone construction and dioptric apparatus; the Nova Scotia lighthouse commissioners on the other hand, opted for wooden towers fitted with catoptric apparatus. This decision was not solely based on economy; the governor made known in a despatch to the colonial secretary on 23 March 1838 that to proceed otherwise would have resulted in considerable delay.

Wood, although less durable than masonry, was frequently preferred in Canada due to its abundance. The New Brunswick lighthouse commissioners, for example, showed a preference for wood or frame construction for this reason. Normally one would not expect a frame tower to be as durable as a masonry structure, although a number of timber and frame lighthouses have in fact stood the test of time. One of these is the Gannet Rock lighthouse, a rock station 7 miles off the southern tip of Grand Manan Island. This lighthouse, built in 1831 and, apart from the lantern, still in its original state today, was the object of critical remarks on the part of the master of HM sloop *Persian* in 1851. A New Brunswick lighthouse commissioner's defence of the structure has been borne out surely by the test of time.

The building is of wood, as are all the Light Houses of the Province, but this one is of the very best construction, a frame of heavy timber, boarded and shingled in a good state of preservation and repair. The lower flat or first storey is studded off from the frame lath'd and plastered.[8]

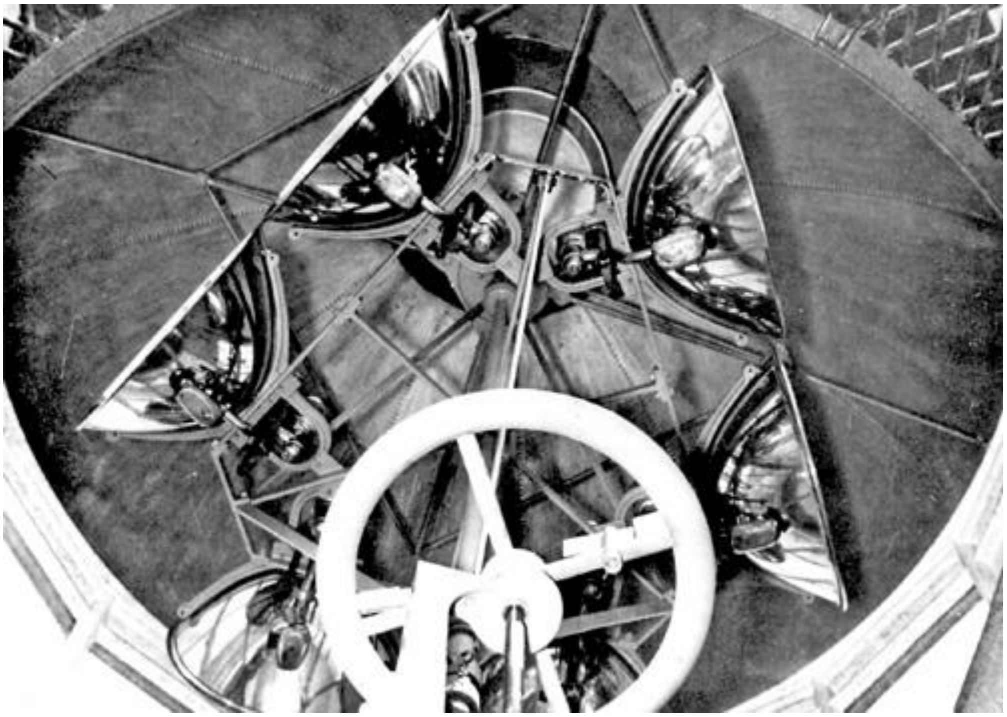
Many circular cast-iron lighthouse towers were built along the shores of Newfoundland and were the subject of much dispute. The imperial authorities (Board of Trade and the Admiralty) who built the majority of the more important lighthouses in Newfoundland favoured this type of construction. Local authorities frequently took issue with this imperial predilection for iron towers. Robert Oke, a celebrated Newfoundland lighthouse authority, in his report for 1856 inveighed against the unsuitability of iron towers in so damp a climate. A case in point was Cape Race tower; condensation and hoarfrost on the interior walls had made the living quarters uninhabitable. A marginal notation within the report indicates that the Board of Trade had been warned of this possibility beforehand. A visiting Canadian engineer. G. F. Baillarge, supported this contention on a visit to Newfoundland nearly 10 years later. Sir Alexander Bannerman, the lieutenant governor, made the same point in a despatch of 22 December 1857, contending that brick was the most suitable material for use in Newfoundland. Iron towers found favour because of the very little maintenance required compared with brick and masonry. In 1878, the Newfoundland inspector of lighthouses and public buildings strongly recommended an iron tower for the projected Cabot Island lighthouse. Brick and stone required annual maintenance, even in the case of the best materials, whereas iron required but a little paint to counteract corrosion. The subject remained a debatable one in Newfoundland.

John Page, Canadian chief engineer, in his report for 1859, favoured stone work to brick for exterior surfaces. Brick did not lend itself so well to circular construction. Wood, brick and stone had all been used in lighthouse construction throughout British North America, wood being the most prevalent, particularly on inland waters. The wooden St. Paul Island lighthouses had withstood the ravages of wind and weather in that stormy location for the previous 20 years. Page completed his observations with the conclusion that the objection to iron towers was the danger of instability, and that mode of construction should only be resorted to at sites where stone and brick were not available and costly to transport from a distance. The soundest tower design was to be found in France, in which an insulating air space was left between the inner and outer walls to counteract the deleterious effect of dampness. Only stone of uniform grain should be used; generally speaking in Canada granite and limestone were most satisfactory.[14] Reinforced concrete and steel, available in the early years of the 20th century, were to add a new dimension to lighthouse design.

The Canadian engineer previously cited, G. F. Baillarge, found that American pressed brick lined inside and out with Portland cement was a frequently used alternative to the cast-iron tower in Newfoundland. This combination proved moisture-resistant to a high degree, a prime requisite in a climate as damp as that of Newfoundland. Based on a stone foundation, this type of construction frequently was combined with three or four courses of freestone at the topmost levels, ostensibly the better to withstand the effects of weathering in windswept locations. The freestone was brought in from Wallace, Nova Scotia, priced at 30 to 60 cents per cubic foot. The Boston region supplied the American pressed brick at $7 per thousand.

The Department of Public Works records offer considerable construction detail on the Cape Jourimain lighthouse (Cape Tormentine) completed in 1870. This is worth citing, not because there was anything unusual about this tower but rather because it was representative of the period. It was a timber and frame eight-sided tower 51 feet in height, the sloping sides tapered from a 20-foot length at base to 9 feet at the top. There were four storeys including the lantern room. The joists at ground level and the first storey were 13 inches deep and 4 inches thick. The sides, floor and hatchway of the lantern were sheathed in galvanized iron as a fire preventive. From ground level to the lantern platform the tower was covered with high-quality shingling, and above this level with galvanized iron. The cost of construction, including a dwelling, was $2,974. The light was ready for service by 5 January 1870.

A perusal of the Admiralty light lists compiled in 1884 covering the coasts and inland waters of British North America indicates that lighthouse towers generally followed a circular, square or octagonal design. The tabular statement of lighthouses for the (pre-Confederation) Province of Canada on the eve of the federal union lists square frame and stone towers as recurrent types in what were shortly to become the provinces of Quebec and Ontario. Brick was not in common use in this region. Hexagonal and octagonal towers were not uncommon with one light at Coteau-du-Lac described as "on top of a house."



3 Cape Bonavista light with parabolic reflectors fitted with Argand burners.

The new century, which has so featured accelerating technological change, gave early confirmation of this trend both in lighthouse construction and apparatus. Reinforced concrete and steel skeleton towers made their appearance in the early years of the 20th century. The tower installed at the north end of Belle Isle in 1908, which went into service the following spring, was a cast-iron structure built in sections by the Montreal firm of H. R. Ives. A coat of reinforced concrete was applied a few years later, the whole supported by buttresses resting on rock.

An early forerunner of the now familiar skeleton steel tower was ordered by the Department of

Public Works for the north pier at Kincardine, Ontario, in the spring of 1903.[20] Point-au-Baril lighthouse on Georgian Bay (Lake Huron) was of similar design, and was installed the same season. As with most towers of this type, these were square with sloping sides imparting a tapering shape to the whole. The Varennes light in Quebec was a third early installation. Both reinforced concrete and skeleton steel towers had won general acceptance and were to be found at a number of locations by 1917.

Sable Island posed a challenging site for lighthouse construction. In an utterly exposed location far out in the Atlantic, the desolate and notorious island, by reason of its continually eroding and shifting sands, never allowed for permanence of installation. The first pair of lighthouses, wooden structures at either end of the crescent-shaped island, date from 1873. A lighthouse of skeleton steel design was installed in 1917. Built by the Dominion Bridge Company in Lachine, the tower was shipped in sections to Dartmouth at a total cost (fob) of $3,836. An individual foundation for each of the four legs of the tower was provided to a depth of seven to eight feet, in order to cope with the ceaseless undercutting of the sand by the wind. Re-assembled on the site, the work was completed and the light in operation by 18 December 1917.[22] Only nine years later, the corrosive action of the salt air had had its effect on parts of the tower. In 1935 a concrete tower was recommended for Sable Island on the grounds of steel's rapid corrosion at such a location. Nonetheless. a decision in May of the same year again favoured open-work steel construction, still in use today at the site.

A cast-iron cylindrical tower was designed and built at the Prescott depot, complete with lantern and optical apparatus, for assembly at Cape Norman in the Strait of Belle Isle in 1906. Cape Bauld, in the same region on the northern coast of Newfoundland, was being provided for in similar manner the same year. These two installations featured the long familiar circular cast-iron construction but were of Canadian manufacture.

Post-1945 tower construction felt the rapid winds of change. In 1952 an offshore lighthouse, the foundation for which was a cellular crib of reinforced concrete built in the Sault Ste. Marie drydock and towed to the site, replaced the lightship on Gros Cap Reef, Lake Superior. On the cribwork filled with concrete, whose prow-shaped foundation was especially designed to withstand ice pressure, rested a lighthouse, fog alarm and radio. This offshore installation resembles the forepeak and bridge of a lake freighter.

The White Island Shoal lighthouse, replacing a lightship in Lake Superior in 1955, and the Prince Shoal lighthouse on the lower St. Lawrence are of similar design. The foundation consists of a steel pier in the form of a cone on which rests an inverted cone of similar dimensions, its top thus providing a circular flight deck for the reception of helicopters as well as a base for the light and radio installations.

CHAPTER III

Apparatus: Lights and Optics

The Whale-oil Lamp

The principal handicap of the oil-fed lamp has always been the smoking of the wick, depositing a film of soot on the lantern glazing and so decreasing rapidly the effectiveness of the light. This centuries-old problem was overcome in 1782 by an invention by the Swiss, Ami Argand, of a virtually smokeless oil lamp utilizing a circular, sleeve-like wick through and around which was a free circulation of air, much improving combustion. The lamp, soon to be known by the name of its inventor, was enclosed within a glass chimney reminiscent of the coal-oil lamps used by our grandparents before the age of hydro. The Argand burner produced a clear, relatively smoke-free flame. By 1820 some 50 lighthouses along the shores of England and Ireland were fitted with Argand lamps; indeed 60 years later there were still numerous lighthouses in the British Isles so equipped.[1] A further refinement and improvement of the simple Argand burner was the multiple-wick lamp devised by Count Rumford (Sir Benjamin Thompson), American-born scientist and founder of the Royal Institution in 1800.

Parabolic Reflectors: Catoptric Principle

The whale-oil lamp on the Argand principle was still inferior in illuminating properties to a well-tended blazing coal or wood fire. To remedy this deficiency, the Swedes hit upon the use of the parabolic reflector of polished steel as early as 1738, in order to focus the light on the required plane. At Orskar, five parabolic mirrors were fitted with ten burners, but these initial experiments were disappointing mainly because the lamps were not set at the exact focal point of the mirrors.[2] By 1763 a crude type of parabolic reflector was introduced to certain lights along the Mersey in England, but again results were not encouraging. It fell to J. A. Bordier-Marcet of France to perfect what came to be known as the "catoptric system" (from the Greek *katoptron,* a mirror). His *fanal à double effet* employing two reflectors and two Argand lamps won general favour in the French lighthouse service by 1819. Bordier-Marcet's next optic, the *fanal sidéral* or star-lantern, utilized two circular reflecting metal plates, one above and one below the flame, projecting the light in a parabolic curve horizontally. In essence, this device reflected the vertically emitted light to the horizontal plane. Mariners at Honfleur, where the star-lantern was first introduced, enthusiastically dubbed it *notre salut.* This device increased the candle power of an ordinary Argand lamp from 10 to 70 candlepower, a seven fold improvement.[4] Catoptric apparatus was used in the Canadian lighthouse service until late in the century because of its relative economy, but in Europe and the United States a light upon an improved principle had largely displaced the simple reflector type by the 1830s and 1840s.

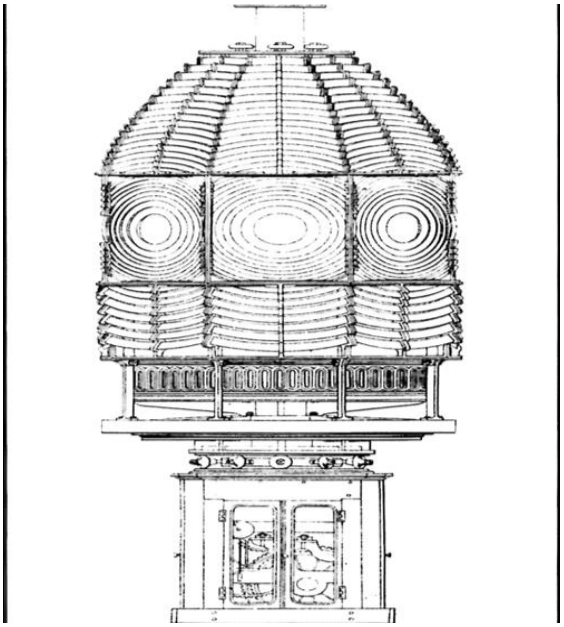
The following passage quoted from the minutes of the New Brunswick Executive Council in 1846, describing the apparatus at Machias Seal Island at the entrance to the Bay of Fundy, illustrates the limitation of the older style catoptric installations with multiple lamps and reflectors.

> *The Lighthouse lanterns have eight parabolic reflectors of 23 inches diameter, set in a circle of 16 feet circumference, with one large Argand lamp to each, each lamp having a pipe of communication with a common reservoir in the centre, in which oil is kept fluid in winter by an Argand lamp burning under the reservoir—the lantern is only seven feet in diameter, so that the lighthouse keeper really has no room for the necessary operations of feeding and cleaning, and the glass of the outer frame is so near the lamps as to be constantly misted.*

By contrast, the largest dioptric light of much greater power than the above installation, 6 feet in diameter with but one lamp, was many times more convenient to service.

Lenses: Dioptric Principle

In 1823 another Frenchman, Augustin Fresnel, perhaps the most celebrated of all the pioneers in lighthouse optics, introduced the first lenticular, or dioptric, lighting apparatus in the Corduouan lighthouse located at the mouth of the Gironde River. The principle of the dioptric (Greek *dioptrikos,* to see through) system was the refraction, by means of lenses and prisms, of light on the desired focal plane. Unlike the catoptric, the dioptric apparatus used only one lamp or light source. At the time of the installation of the first lenticular light in the Corduouan lighthouse in 1823, the facility was considered second to none in the world. The cutting and grinding of lenses called for craftsmanship of a very high order, and so lenticular apparatus was costly, but once installed it required no adjustment. By mid-century both refracting and reflecting elements were combined in the one optic, known as the catadioptric system, but in practice the shorter term continued to be used. By this time, lenticular or refracting lens apparatus had supplanted the simpler reflector type in most of the world's principal lighthouses.



4 Drawing of 1st Order revolving light, the type used in major landfall lights. Note elaborate prisms required for oil lights.

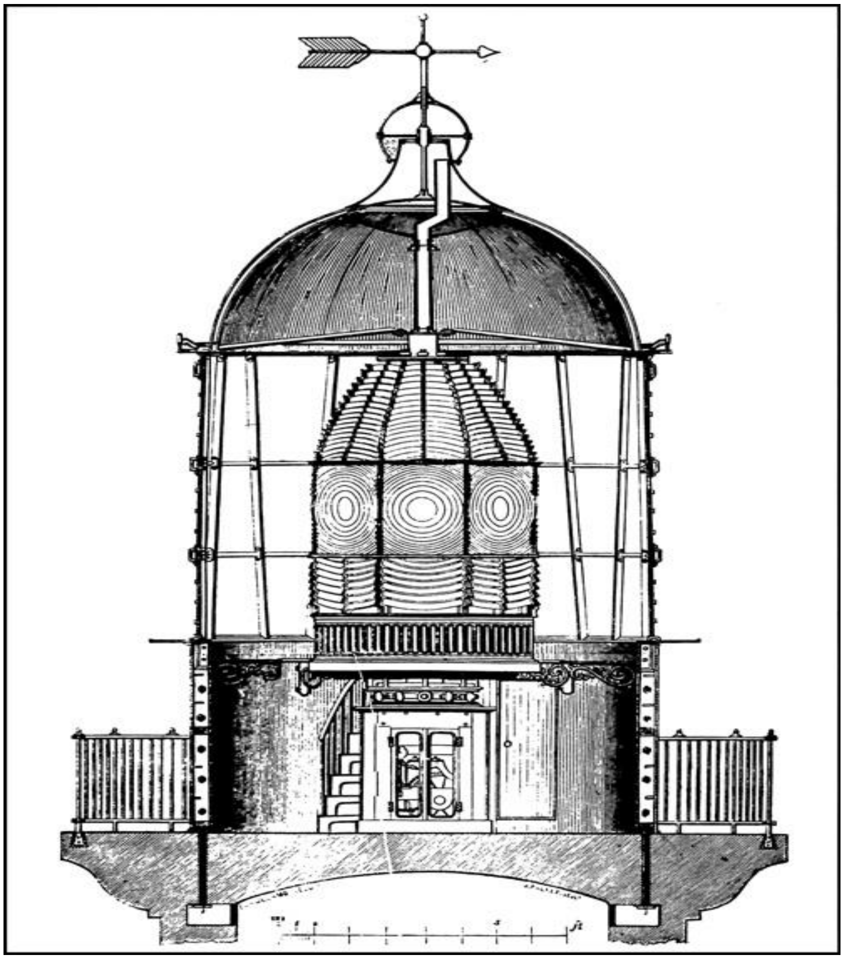
It will be readily appreciated that France was the leading country in the field of lighthouse optics in the early 19th century; particularly was this the case in the fine craftsmanship required for the production of lenticular or dioptric apparatus. In England as early as 1831, the South Shields firm of Isaac Cookson and Company endeavoured quite unsuccessfully to match French quality. The turmoil in France in 1848 drove a number of refugees to seek asylum in England, among whom were Georges Bontemps and an engineer, Tabouret, who had gained an invaluable apprenticeship under the great Fresnel. These two fugitive craftsmen from the continent were engaged by the Birmingham firm of Chance Brothers, a concern which had been commissioned by the government to manufacture dioptric lighthouse apparatus for use on the English and Irish coasts in 1845. As a result, by 1851 Chance Brothers could boast a product on a par with that of their French forerunners and future competitors.[6] The English firm enjoyed a monopoly in its field for many years in Britain and its products were exported to all parts of the world. Throughout the 19th century, until the debut and gathering experience of the Dominion Lighthouse Depot in the early years of this century, Chance Brothers supplied a large portion of Canada's requirements.

As early as 1845, the imperial Trinity House had expressed a decided preference for the dioptric type of light. This also was the trend along the American seaboard, where their numbers increased from three in 1851 to no fewer than 310 five years later. Indeed the American authorities announced a programme of total replacement of the old reflector-type lights, whereas as late as the year 1860 there were but 10 dioptric lights in service in the old Province of Canada. By this date there was no doubt concerning the superiority of the dioptric or refracting light. Assuming equivalent oil consumption, the dioptric apparatus emitted a light five times the strength of the catoptric.[8] Furthermore, as previously indicated, one light source sufficed with the dioptric system whereas the catoptric required multiple lamps. One cannot do better than to quote a report compiled by a British engineering firm, D. and T. Stevenson, for the Commissioners of Northern Lighthouses, about the year 1850.

> *It has been determined that in revolving lights, the effect of one of the eight annular lenses, in a First Order Light, is equal to that of eight of the largest reflectors in use; and that to produce by reflectors to the most perfect kind the effect of Lenticular apparatus of the best description, a lantern must be provided capable of accommodating from fifty-six to seventy-two reflectors; an arrangement all but impracticable.*

Dioptric lights were classified according to the internal diameter of the optical apparatus: the largest, lights of the 1st Order, designed for installation in landfall lighthouses, were 72-1/2 inches in diameter. The smallest, lights of the 6th Order used as harbour lights, were less than a foot in diameter. Lights of the 2nd Order were used in coastal lighthouses, to be found frequently at the mouths of large rivers or in the vicinity of dangerous shoals.

This elaborate construction of precisely ground lenses and prisms has survived to the present, although invariably the light source is now electric. Current electric lamps, because their light source is so concentrated, do not require such complex refracting optical apparatus as their predecessors. Nonetheless, dioptric apparatus of the type depicted in Figure 4 has continued to be used with an electric light source at major lighthouses. As this apparatus is replaced over the course of time, much simpler and less costly optical apparatus will be used with comparable effectiveness.



5 1st Order dioptric revolving light in lantern. This apparatus represents the culmination of the 19th century. *(Public Archives of Canada.)*

The Coal-oil Lamp

Until the 1850s in British North America, lighting apparatus was based on the Argand burner with its reservoir of sperm oil, with variants of porpoise or fish oils in maritime regions. At going rates in 1861 of $1.69 to $1.85 per gallon, the traditional sperm oil was expensive and likely to become more so due to the diminishing supply. Already by the early sixties far-ranging whaling fleets operating in the southern seas had depleted the whales. The British and French lighthouse services had in large measure turned to the use of vegetable oils such as colza and rape seed, which was at once cheaper and more readily available. In 1860 John Page, in his report to the Commissioner of Public Works, observed that Canadian experience confirmed the superiority of colza to sperm oil. Although a larger quantity of the vegetable oil was required to produce an equivalent effect, the cost was little more than half that of the traditional material. Despite the fact that lighthouses in the British and French service had converted with few exceptions to the use of colza oil (the source for which was France and Holland), at the time lighthouses both in the Province of Canada and in the United States were still largely dependent on sperm oil.[11]

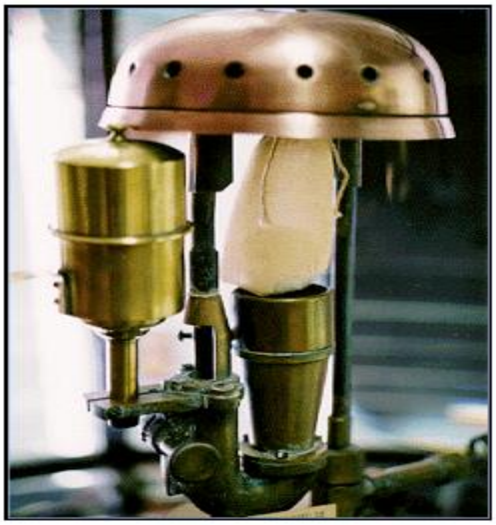
A highly significant Canadian contribution to both the lighthouse service and to domestic lighting in general was the distillation in 1846 of kerosene from coal devised by Dr. Abraham Gesner, a physician from Cornwallis, Nova Scotia. Although having taken a medical degree in London in 1827, Gesner later forsook medicine for geology, in which field he made a major contribution to the development of lighthouse illuminants.[12] Popularly known as "coal oil," kerosene was first tried in the early sixties in lighthouses on the upper St. Lawrence between Beauharnois and Kingston. According to Superintendent D. C. Smith, coal oil "afforded much better and more brilliant light than the sperm oil." At a cost of a mere 65 cents per gallon, coal oil offered the strong inducement of economy. In 1864, Smith recommended the total conversion of all lights in his agency to coal oil, and received the chief engineer's sanction the following year. Mariners plying the upper St. Lawrence reported enthusiastically on the effectiveness of the new kerosene lights.

Although there was no doubt but that coal oil produced both a brighter and steadier flame with catoptric apparatus, John Page cautioned against its use with dioptric apparatus which was gaining favour for the more powerful lights. Coal oil used in the concentric ring burners required to produce "the large, uniform shape and density of flame required for lights of this class" would have insufficient combustion to be effective.[15] But for reflector or catoptric lights coal oil provided at once a much cheaper and more effective illuminant. Until late in the century, this older-style apparatus was still favoured in Canada. In 1861 coal oil was introduced with excellent results at the Father Point lighthouse on the lower St. Lawrence.

Until the advent of petroleum vapour and acetylene lamps early in the 20th century, the circular-wick burner using colza oil and the flat-wick lamp using kerosene held sway in the Canadian lighthouse service. Figure 7 illustrates flatwick coal-oil lamps, so favoured for use with the more numerous catoptric lights until the end of the century. The mammoth burners were fitted with 18- and 24-inch reflectors; their kerosene consumption ran at about double the rate of the smaller models. These kerosene lighthouse lamps, some of which were still in service until post-war years, remind one of the domestic coal-oil lamps which were so much a part of rural households in our grandparents' generation. In the main, these two basic lamp types, fitted with more elaborate refracting and reflecting elements, saw the Canadian lighthouse service through into the early years of the present century.

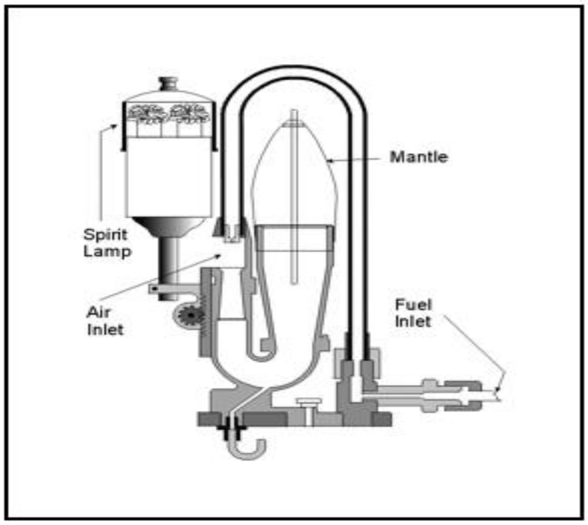
The Gas Mantle

Around the turn of the century an ingenious device utilizing a familiar illuminant was introduced to lighting technology and survived at some locations well into the post-war period. The incandescent oil vapour light was first installed at L'Ile Penfret lighthouse in France in 1898. The novel principle, trebling the power of all former wick lamps, consisted of the burning of vaporized coal oil within an incandescent mantle. In England Arthur Kitson perfected a lamp on this principle which became well-known as the "Kitson burner," and by 1902 this equipment was widely adopted in the British lighthouse service. In 1921 David Hood introduced an improved mantle of viscous silk doubling the brilliance of mantles up to that time. By 1904 petroleum vapour lights had captured the attention of the Canadian authorities, not surprisingly. inasmuch as a 345 per cent increase in candle power was claimed for the oil vapour lights compared with the flat-wick lamp. The new lights came in four sizes ranging from 25 to 85 millimeters.[17] Although the well-established English firm of Chance Brothers was credited with producing the best quality petroleum vapour lights at the time, an early Canadian competitor in the field was the Diamond Heating and Lighting Company of Montreal.[18] As early as 1909 a 1st Order dioptric apparatus at the Heath Point lighthouse, Anticosti Island, produced a brilliant light of one-half million candlepower.



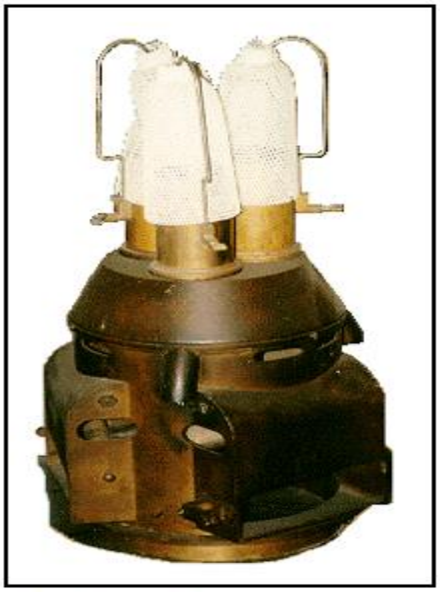
(Photo from Author's collection)

French Luchaire I.O.V. Lamp. (ca. 1904)



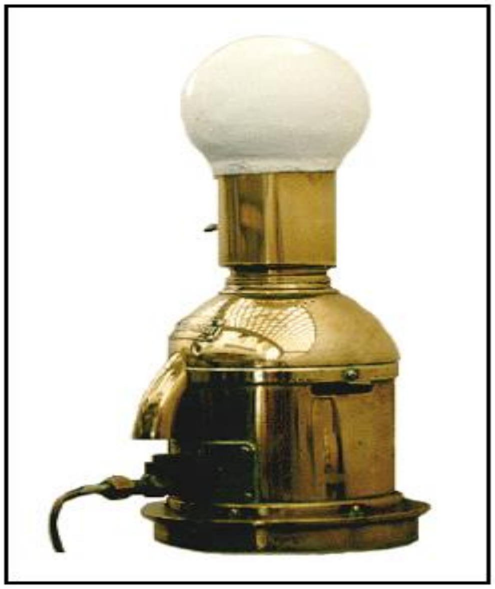
(Drawing by Author from official drawing)

French Luchaire I.O.V. Lamp Burner cutaw



(Photo from Author's collection)

Chance Brothers' version of a triple mantle I.O.V. Lamp. (ca. 1911)



(Photo from Author's collection)

D. W. Hood I.O.V. Lamp with autoform mantle. (1921)

8 Oil vapour lights with incandescent mantles, introduced in the 20th century, this apparatus gave a much brighter light.

A concurrent development of the early 20th century and one to find increasing favour with unwatched lights was that of the acetylene light. First tried in Canada in the Father Point lighthouse in 1902, the acetylene light was reported on favourably by mariners. It was claimed that the range of this reflector-type light was increased from 14 to 28 miles as a result of the conversion. In 1903 the department decided to convert all the kerosene lights on the upper St. Lawrence to acetylene and tests conducted that same year demonstrated a five-fold increase in candlepower over the former kerosene flat-wick lamps. On the whole, the acetylene light was more applicable to use in buoys than in lighthouses. The advantage of acetylene was that it could be left untended for a period of time, a factor which became significant in the lighthouse service at a much later date. An untended kerosene device, the Wigham lamp, which could be left to its own devices for up to a month at a time, was manufactured in Dublin. The principle of this lamp, which found favour on the Pacific coast, was that of a horizontally burning wick fed slowly over a roller, the burner surrounded by a combustion cone and fitted with lenticular optical apparatus. Although both petroleum vapour and acetylene were to be eventually supplanted by electricity, both were in service at scattered locations in very recent years.

Revolving Lights and Colour Characteristics

Until late in the 18th century, all lighthouses exhibited fixed white lights. The first revolving light to sweep the horizon with its beam was tested at Carlston, Sweden, in 1781. By 1790 revolving lights had been widely adopted in the French and British services. Weight-driven clockwork, on the same principle as that used in grandfather clocks, provided rotary power until the advent of the electric motor. The early revolving lights were restricted in size because of frictional losses produced by the light's rollers in the raceway; friction was overcome by 1890, with the introduction of the mercury float mechanism, removing at one stroke the principal restriction on the size and weight of the intricately designed apparatus. The first such light in Canada was installed at Southwest Point, Anticosti Island in 1831. Its beam completed a revolution 100 feet above high water every minute.

Figure 9 illustrates the two systems of rotary gearing in common use about the middle of the last century. The French system employed offset gearing, and the Scottish, central. Greater stability and smoother operation was claimed for the latter, conditions which were very important with apparatus of great weight.

Rotary Tattoo machine

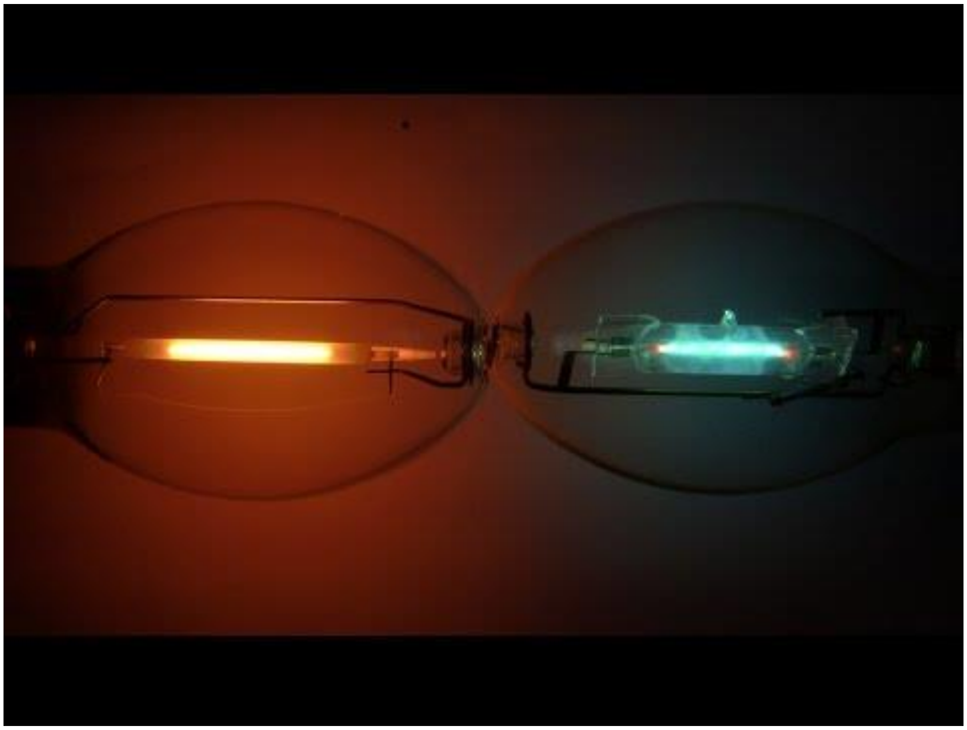
Although it was early known that white light was visible at a greater range than coloured, the desirability of colour characteristics in the interests of readier identification was admitted. To an English customs agent, Benjamin Milne, goes the credit for devising the first colour characteristics in lighthouse optics. Produced by 21 parabolic reflectors mounted on a three-sided frame, the whole rotated by means of a vertically mounted axle. The reflectors on one of the three sides were covered with red glass, producing a red beam periodically followed by white.

This apparatus was installed in the Flamborough Head lighthouse on the Yorkshire coast in 1806. Light colours now used internationally are white, red and green. White is preferred because of its range, which exceeds that of red or green.

Light Characteristics

The trend in the early years of the 20th century was the replacement of catoptric by dioptric apparatus, increased power in lights generally, and the replacement of fixed with flashing and occulting lights in the interests of easier identification. The flashing light displays its beam for a briefer span than the subsequent period of darkness, or eclipse; the reverse is the case with the occulting light. In order to render identification yet more certain, combinations of flashing and occulting sequences, sometimes with the additional feature of a colour phase, were devised for different locations. Below are shown the characteristics of lights that are exhibited internationally,

1. *fixed*—continuous or steady light: little used today.
2. *flashing*—single flash at regular intervals: duration of light less than darkness.
3. *group flashing*—a group of two or more flashes at regular intervals.
4. *occulting*—steady light with a sudden and total eclipse at regular intervals, duration of darkness being always less than or equal to that of light.
5. *group occulting*—steady light with a group of two or more sudden eclipses at regular intervals.
6. *fixed flashing*—a fixed light varied by a single flash of relatively greater brilliance at regular intervals,
7. *fixed and group flashing*—a fixed light varied by a group of two or more brilliant flashes at regular intervals.
8. *quick flashing*—a light that flashes continuously more than 60 times a minute.
9. *interrupted quick flashing*—same as preceding but with total eclipse at regular intervals.
10. *group interrupted quick flashing*—same as above, but with relatively longer periods of eclipse.
11. *alternating*—any of foregoing but which alter in colour.[25]



Electrification

Electricity for lighthouse purposes was tried first at South Foreland, England, as early as 1858. The first electric light in regular service was at the Dungeness lighthouse on the coast of Kent in 1862. The results cannot have been encouraging, for both prototypes were subsequently replaced with the reliable mineral oil lights. The practical adaptation of electricity to lighthouse use was contingent upon two developments; inexpensive transmission of electrical power (or self-contained generating equipment) and the tungsten filament lamp or bulb, the forerunners of which were too short-lived to be practical. In Canada, hydroelectric power became readily available for domestic and industrial use during the first decade of the 20th century and tungsten filament lamps were on the market by 1907. Reed Point, New Brunswick, was the first lighthouse in Canada exhibiting an electric light (1895), but the first electrically operated light and fog alarm was established at Cape Croker, Georgian Bay, in July 1902. The Ottawa firm of A. Trudeau furnished the generating plant.

Electrification continued apace in the inter-war years, and was completed following World War II. The Commissioner of Lights for the season 1914-15 listed a total of 23 electrically equipped lighthouses of which 8 were in Nova Scotia, 6 in British Columbia and 5 in Ontario.[27]

By 1931, electricity supplied both light and rotary power in an increasing number of lighthouses. Known as "multi-flashing apparatus" this equipment was first given a trial in 1930 at Musquash, New Brunswick, and at Cranberry Island and Guion Island, Nova Scotia. And so compact electric motors came to replace the clockwork and weight mechanisms of yesteryear. Experimental work at the Prescott depot delved into the use of cellophane to impart colour characteristics, safety devices for the protection of optics and, most significant for the future, the now widely used mercury vapour lamp. The advantage of the latter, which is now recently replacing the filament lamp, is greatly extended life, running to many thousands of hours. Electrification of Canadian lights was completed following the Second World War, although the acetylene or oil light has survived in some locations.

Of equal significance in the evolution of the modern lighthouse service at home and abroad was the introduction of the automatic, or untended light. Gustaf Dalen (1889-1937) of Sweden, a brilliant engineer tragically blinded in an accident early in his career, invented the first automatic beacon lighting using acetylene, an innovation which won him a Nobel Prize in 1912. He is also credited with the invention of the first sun valve, a photometric device activated by light, switching the light off once dawn had broken and on with gathering dusk. With the passing of the years more and more lights could be left untended. The advantage of automation, particularly with the introduction of the automatic lamp changer, was particularly obvious for lights in remote locations in the north. Today in Canada the function of the traditional lighthouse keeper is being rapidly phased out in his stead is the itinerant technician making his rounds at periodic intervals by motor, supply ship or helicopter.

The principal post-war developments in the more than two-century evolution of the Canadian lighthouse were the completion of the electrification programme, introduction of radar aids to the lighthouse service (for example radar reflectors), and the conversion of a great many lighthouses to automatic and untended operation.

The completion of electrification in the post-war years was made possible by the extension of hydro-electric power to regions hitherto without it, and of yet greater significance, by the widespread introduction of diesel generating units. By this means the convenience and efficiency of electricity was introduced to the high Arctic. As early as 1948, 481 of 2,469 lighthouses and navigational lights had been electrified. At time of writing (1970) virtually all lighthouses throughout the country have been converted to electricity, as well as a good many buoys.[29]

Hand in hand with the electrification of lighthouses previously equipped with acetylene or oil vapour apparatus went the development of new high-intensity electric lights. Many of these were installed in the original dioptric lens and prism apparatus; but with the much greater concentration of electric light, very much simpler optics of moulded glass and plastic served equally well at a fraction of the cost. In its report for 1951, the department observed that "major high intensity electric units established for trial service have been favourably reported." The superiority of the new mercury vapour bulb over the incandescent lamp was obvious by 1961, the advantage being a light of higher intensity and much longer life; these much smaller bulbs lasted for two or three years, an important consideration with the trend toward unwatched lights.

A new, lightweight, anti-corrosive aluminum alloy lantern was introduced in 1955. These gradually will replace the heavy cast-iron types with anticipated lower maintenance costs. The xenon light developed in Britain and Germany, one of which was installed at Prince Shoal in 1964, produced a light of such unprecedented intensity (32 million candlepower) that it is used only in thick fog.

Electronically operated remote control systems, developed jointly by the National Research Council and the Department of Transport, were designed to operate both lights and fog alarms. The offshore Pelee Passage lighthouse in Lake Erie was the first light station so equipped. The significance of automatic remote control for light stations in remote locations in the far north was obvious. A microwave control system was introduced at the Holland Rock fog alarm near Prince Rupert in 1961.

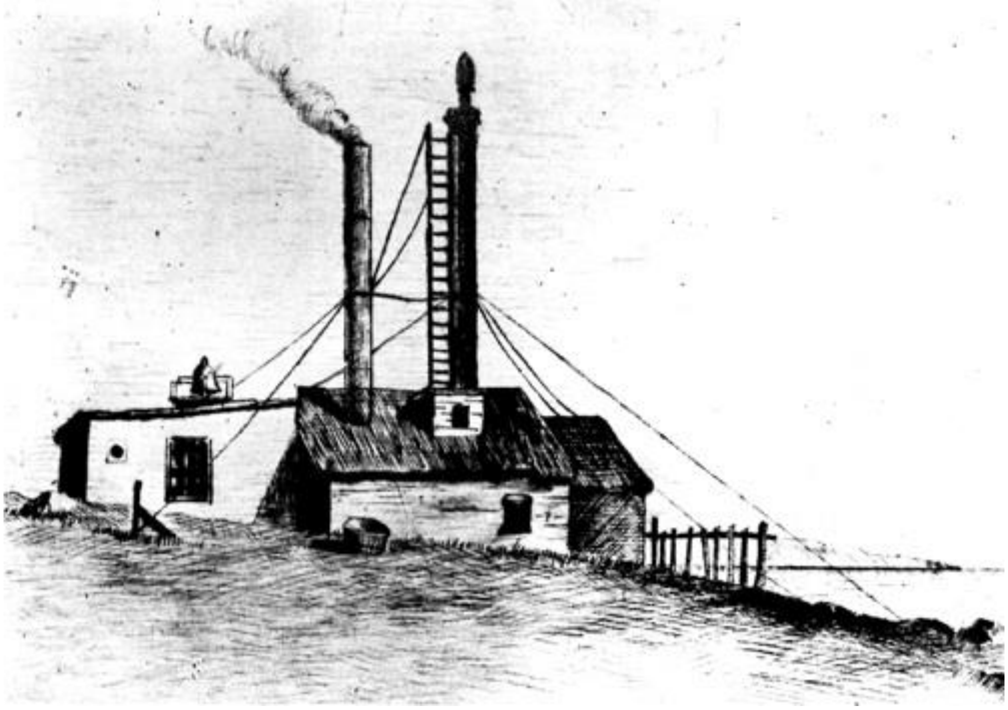
Conversion to electricity was more than two-thirds completed by 1961; of the 3,054 lights in service (including buoys), 2,518 were in automatic operation.

Fog Alarms

From earliest times various devices had been used at light stations to sound fog warnings in thick weather, Bells, gongs and cannon were all tried at various times and places with varying effectiveness. It was well known that sound transmission over water was subject to peculiar and capricious vagaries, a signal sometimes becoming inaudible close inshore while easily heard farther out to sea. Fog signals due to deflection or echo often gave false bearings. Such difficulties have yet to be resolved completely.

The first steam fog whistle in British North America was installed in 1860 at the Partridge Island lighthouse in Saint John Harbour. Mariners were enthusiastic over the installation, consisting of an 8-horsepower engine producing a pressure of 100 pounds per square inch and costing £350 local currency. Its range in calm weather was established at 10 miles. The whistle was controlled by clockwork, sounding 10 seconds in each minute.

In 1899, a fog siren was introduced at Belle Isle halfway between the upper and lower lights at a cost of $20,112.64. Power to drive the air compressor was derived from a waterwheel. The signal was produced by a double siren driven by compressed air; the siren was located 250 feet above high water, and the air compressor in a power house at the landing stage. The equipment was English-made[36] and, along with a somewhat similar device known as a "Scotch siren" also of British make and in use at Louisbourg and Father Point, gave the best results before the appearance of the diaphone, the product of a Canadian inventor.



Drawing of the first steam fog alarm installed at Partridge Island lighthouse at the entrance to Saint

John Harbour, New Brunswick. *(Public Archives of Canada.)*

Diaphone Apparatus

In 1902, J. P. Northey, a Toronto manufacturer, developed the diaphone, a major improvement in fog alarm equipment and one still in widespread use today. Basically a modification of the Scotch siren and operating on the principle of a high-velocity pulsating piston rather than a rotating drum, Northey's diaphone produced a blast of more constant pitch for about one-eighth the power expended by the Scotch siren. By 1904, diaphones had replaced the older fog alarm equipment at most of the important light stations.

The new diaphone equipment required skilled attendants known as "fog alarm engineers" at major light stations. This attendant shared the keeper's meagre salary. Some lightkeepers, more versatile than their fellows, qualified as fog alarm engineers and so could dispense with assistance. The larger diaphones were fitted with steam-driven air compressors, but the smaller installations were petrol operated.

The diaphone continued in use throughout the country, notwithstanding the introduction of electronic aids. In 1952, engineers developed a new resonator which greatly increased the audible range. In the mid-sixties Canada once again contributed to fog alarm development with the "Airchine." The Airchine was not designed to replace the diaphone, the largest of which were unsurpassed in range. The Airchine did, however, offer the signal advantage of economy with a signal of almost comparable range. Its air compressors were driven by small electric motors, the whole plant being about one-fifth the dimensions of the standard diaphone. The first Airchine went into service in 1965.

The electronic fog alarm, a curiously shaped structure of English manufacture, must be considered a major departure in the more than a century's progress in this field. This Stone Chance apparatus has been reported highly satisfactory in the Canadian service.

Submarine Signaling Apparatus

Submarine signaling apparatus, an invention of A.J. Mundy of Boston and Professor Elisha Gray, was another fog alarm system introduced at major light stations early in the century. It was based on an underwater bell connected by cable with the lighthouse; when sounded in foggy weather, the resultant underwater signal was picked up by a direction-finding receiver installed in a vessel's bow. The range of submarine signals varied between 5 and 12 miles.[40] The equipment had its limitations, among which was that very few ships were fitted with direction-finders — the *Tunisian* and *Ionian* of the Allan Line, and the *Mount Temple* and *Lake Manitoba,* early transatlantic CPR vessels. Nonetheless, this equipment was installed at 21 lighthouses under contract to the Submarine Signal Company of Boston.[41] Submarine signaling was quickly displaced by radio in the early twenties.

Radio

Twentieth-century progress in communications was nowhere more apparent than in the fields of radio and aviation, the first of which had an early contribution to make to the lighthouse service in Canada and throughout the world. The first wireless coast station designed for ship-to-shore communications was established at Spezia, Italy, in the summer of 1897. The *Lake Champlain,* launched in 1900 and initially operated by the Beaver Line, was the first passenger liner equipped with radio. Although Department of Marine wireless coast stations were often separate establishments, some lighthouses, particularly in the early days, combined the functions of light station and radio coast station. In 1904, for example, wireless facilities were installed at the Fame Point, Belle Isle, Cape Ray, Cape Race, Heath Point and Point Amour lighthouses. By 1915, no fewer than 21 lighthouses below Quebec were radio equipped. In the same region, Crane Island, Money Point, Point Lepreau and Partridge Island had telephone facilities. By these means, a closer check was kept on ship movements.

Note has already been made of the eccentricities, under certain geographic or climatic conditions, of the familiar bellow and grunt of the fog alarm. The radio beacon installed at a number of radio coast stations and some lighthouses used in conjunction with loop direction-finding apparatus aboard ship was to prove a surer guide to the navigator than the audio signal from diaphone or siren. Cross bearings, however, were themselves subject, under certain conditions, to coastal refraction and hence dangerously misleading. In any case, radio bearings were considered less reliable than visual bearings on a light.

In 1923, the Lighthouse Board recommended the installation of radio transmitter beacons at either the Cape Bauld or Belle Isle light stations, and at Heath Point, Anticosti Island. These experimental radio beacons had a range of about 50 miles. Initially this equipment was to be the responsibility of the lightkeeper. The first radio beacon on the Great Lakes was installed at the Southeast Shoal lighthouse in 1927, transmitting a signal every 2-1/2 minutes on a wave-length of 1,000 meters.

By 1929, radio direction-finding equipment had definitely supplanted submarine signaling apparatus. It should not be overlooked that at this date there were 153 diaphone fog alarms in service, some of which had been operating since 1908. Indeed the fog alarm, as a glance at the latest list will confirm, has been far from displaced; despite the proliferation of electronic aids, mariners still appreciate the discordant blast of the fog horn.[45] In 1929 more powerful radio beacons of 200-watt output became available; this equipment was installed at, or near, the Cape Whittle, West Point Anticosti, and the Pointe-des-Monts lighthouses in the Gulf of St. Lawrence. On the Great Lakes (never behind-hand) similar equipment was supplied to the Main Duck Island (Lake Ontario), Long Point and the Southeast Shoal (Lake Erie), Cove Island (Lake Huron), and the Michipicoten (Lake Superior) lighthouses.[46] The words of the *Liverpool Journal of Commerce* are as applicable to the Canadian as to the British lighthouse service.

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This speculation, dating from 1929, has yet to be fulfilled.

Administration

From 1763 until 1805, boards of commissioners were appointed for specific public works in Lower Canada. In that year, following the British tradition, a corporate body to be known as the Quebec Trinity House was created by statute, with

full power and authority, to make, ordain and constitute such and so many Bye laws, Rules and Orders, not repugnant to the maritime laws of Great Britain or to the laws of this Province. . . . for the more convenient, safe and easy navigation of the River Saint Lawrence, from the fifth rapid, above the city of Montreal, downwards, as well by the laying down, as taking up of Buoys and Anchors, as by the erecting of Lighthouses, Beacons or Land Marks, the clearing of sands or rocks or otherwise howsoever.

In addition to the master and his deputy, two wardens were appointed in Quebec and three in Montreal, a subordinate branch of the parent body. The same bill made provision for divers other officials as a harbour master for Quebec, and at Montreal water bailiffs, superintendent of pilots and a lighthouse keeper at Green Island "with a farm belonging to the Corporation."[2] A little over a quarter-century later, a Montreal Trinity House was instituted, the enabling statute receiving royal assent on 25 February 1832.[3] These two authorities were not unworthy of their namesake in London, co-operating fully with the Admiralty, the imperial boards of trade, and the various boards of lighthouse commissioners in the Atlantic provinces, to be succeeded only at Confederation by the newly created Department of Marine and Fisheries.

By the year 1824, the colony of Nova Scotia was maintaining five lighthouses along its shore solely financed by means of light dues. Apparently the Nova Scotian authorities at this time felt that they were contributing somewhat more than their share in relation to their neighbours, for in the words of a despatch from Government House dated 14 September 1824, "It may not be improper for me to observe here, that from the geographical position of Nova Scotia, the navigation to and from the Provinces of New Brunswick and Prince Edward Island derive very considerable security from its Light Houses."[4] From this date, 1824, more than two decades were to pass before the first lighthouse was built on the shores of Prince Edward Island; but whether the Nova Scotia governor's implication with respect to the efforts of New Brunswick's lighthouse commissioners was well taken is perhaps debatable.

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Mandvi Guest House,Gujrath,India

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A peculiarity until 1848 of New Brunswick lighthouse administration was the existence of two boards of lighthouse commissioners, one of which sat at Saint John and the other at St. Andrews. In 1842, on an address from the House of Assembly, the Saint John board was constituted the sole authority in the colony. This decision was resisted for a season by the St. Andrews body, which refused to sit with its associate. The Saint John board resolved on 27 April 1842, since separate appropriations had been provided, to carry on under the old system for another season while recommending the increased efficiency to be derived from a single authority. By 1848 this policy had obviously been implemented, for in the minutes of the executive council, reference is made to one board of lighthouse commissioners.[12] No doubt this resulted in a saving to the colony.

As with the other colonies, in Newfoundland a board of lighthouse commissioners was responsible for those lighthouses which did not fall under the aegis of the Admiralty. By legislation passed in 1855 the lighthouse commissioners' authority was henceforth vested in the newly created Board of Works, made up of the surveyor general as chairman, the attorney general, the colonial secretary, the president of the legislative council, and three members from the House of Assembly.[13]

By the late 1830s it was obvious that Upper Canada's lighthouse service left much to be desired. In the words of Captain Sandom, master of the *Niagara*, whose strictures reached the Colonial Office,

The total neglect of the local government with respect to the Lighthouses, that a very important one (on Long Point) has literally been allowed to fall to ruin, the oil being carefully stored in the contractors' rooms; another (also important) upon Pelee Island, is in spite of frequent remonstrances by my officers with the keeper and contractor, kept in utter darkness. I am given to understand the "Inspector of Lighthouses" is a sinecure office, at present held by. . .in the City of Toronto.

Notwithstanding Sandom's sharp criticism, the inspector general on his 1839 tour of inspection found the Pelee Island establishment, along with those at False Ducks Island and Nine Mile Point on Lake Ontario, in reasonable order. He observed, however, that the reflectors in most of the lights had been damaged by careless cleaning.

The few good stations notwithstanding, it was nonetheless apparent by 1840 that a closer supervision of lightkeepers was required, and that some attention should be given to apparatus designed to improve circulation of air within the lantern. The purchase of supplies by public contract became mandatory only in 1837. The inspector general recommended that lightkeepers' salaries be paid only on certification that the lights in question had been properly maintained either by ship's captains or local customs collectors. Shortly after the Act of Union, lighthouses in Upper Canada, or Canada West as it was to be known until Confederation, passed under the jurisdiction of the Board of Works. A uniform pay scale was introduced for lightkeepers: £65 per annum on shore stations, £85 on island locations, and a special stipend of £100 per annum for False Ducks Island. A stricter and more stringent selection of candidates for lightkeeping duties was instituted in March, 1844; henceforth, mariners with lake experience would be given preference. Clearly the lax ways of the pre-union period were a thing of the past, including the mischievous practice of hiring deputies (sub-contracting the duties to third parties) which so often had contributed to carelessness and neglect.

But not all complaints could be traced to a negligent keeper. Frequently the sperm oil lamps smoked, darkening the lantern glazing and so diminishing the effectiveness of the light. In December 1844, J. S. Mcintyre reported to the Board of Works that the trouble lay with poor combustion due to inadequate ventilation. The solution to this problem was a properly designed air vent in the roof of the lantern. He also observed that many of the burners were not set at the exact focal point of the reflectors, and to correct this fault he made all of the reflectors adjustable. He also recommended the standardization of all the lamps and reflectors in use on the lakes, and this was later implemented. Other improvements were made in the lamps to regulate the flow of oil to the wick and reduce oil wastage. Of all the lights on the lower lakes, Mcintyre found the worst attended was that at Port Burwell.

It is fortunate that this Light is not of much consequence for it is certainly the worst attended to on the Lakes. The reflectors are of very little use as the lamps are three inches outside of the focus, and there is no way of altering them, without making an entire new stand.

Mcintyre's modifications of apparatus and reforms respecting personnel had their effect, for by 1845 he was able to report that all the lights on Lake Erie were of a new and improved design, as were those at False Ducks, Main Ducks and Point Petre on Lake Ontario.

With the creation of the new Department of Marine, not many years were to pass before it assumed responsibility for aids to navigation from its colonial predecessors in the various provinces of British North America. In 1870, the new federal parliament enacted legislation transferring responsibility for all lighthouses and buoys between Quebec and the Strait of Belle Isle from the Quebec Trinity House to the Department of Marine. The Montreal Trinity House surrendered its jurisdiction in like manner on 1 July 1873.

In 1867 the total number of lighthouses established and in service in the old Province of Canada (Quebec and Ontario) was tallied at 131.

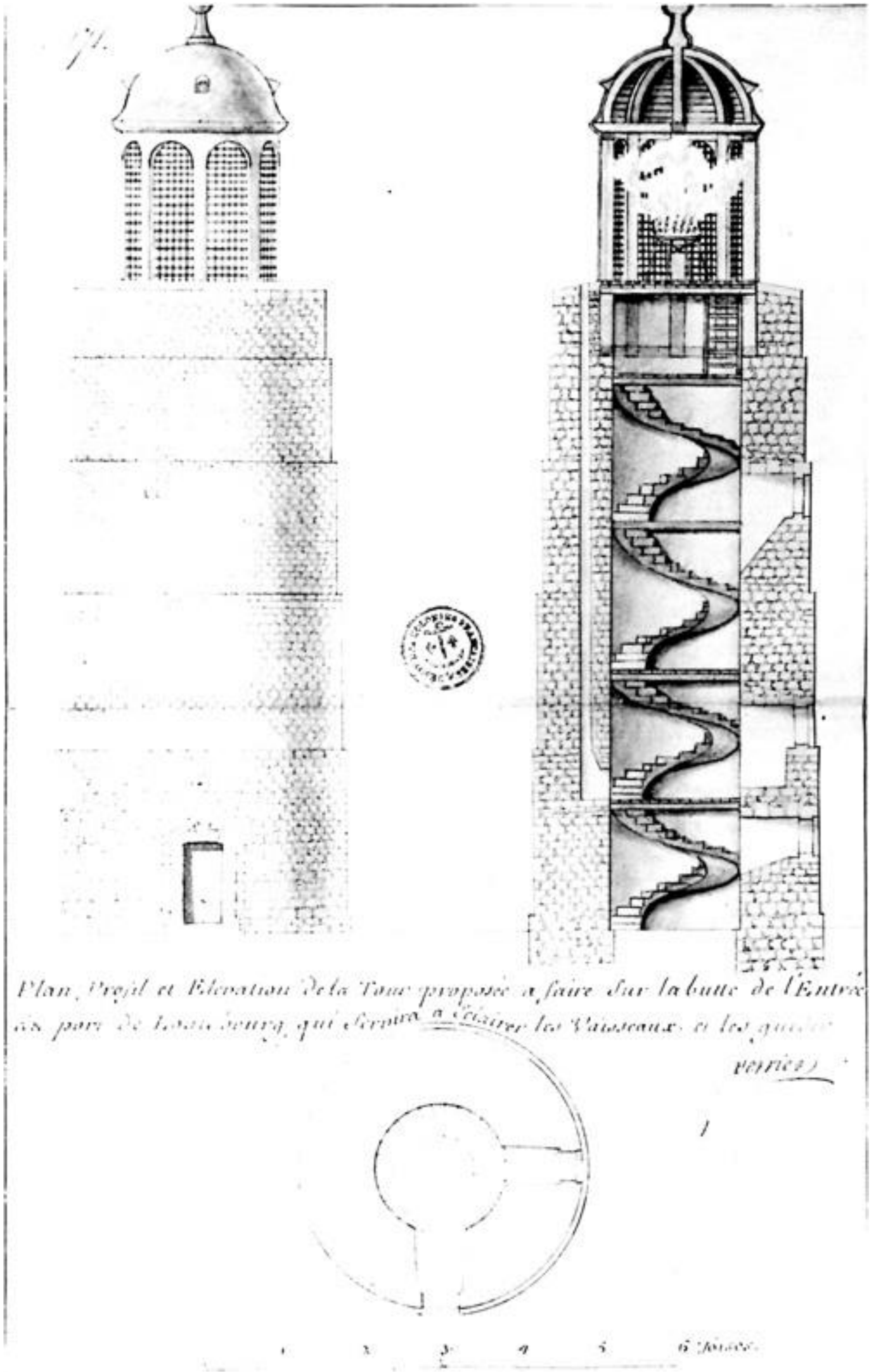
Although this may have seemed at the time an impressive total, with the rapid development of steam navigation the new department early in its career recognized the urgency for both expansion and improvement in quality. The minister, in his fifth annual report (1872) stated,

I was under the necessity of asking for moderate sums, and erecting a cheap description of strong wooden-framed buildings, taking care, however, to use nothing but high-class powerful lighting apparatus: . . . this Department has succeeded in erecting ninety-three new lighthouses and has established four new lightships, and ten new steam fog alarms on the coasts of Canada, besides having under contract forty-three lighthouses, eight steam fog alarms, and two new light ships, all of which has been done within five or six years. The Canadian petroleum oil used for these lights, being a powerful illuminant, and being procured at a very small cost, has enabled this Department to maintain not only brilliant and powerful lights, but to do so at, probably, a cheaper rate than any other country in the world.

In the summer of 1872, a visiting committee of the imperial Trinity House toured both Canada and the United States in order to observe the quality and efficiency of their respective lighthouse services. The visitors found the Canadian lights superior to the American, although the latter service comprised a greater number of solidly built masonry and brick structures. The Canadian service, they pointed out, had to operate on a much slimmer budget and so was one of simplicity and economy, well-suited to the needs of a new country. Lightkeepers were not highly trained as they were in England, nor were they well paid; most Canadian keepers considered their lightkeeping wages subsidiary to other sources of income. According to the visiting Brethren,

Their buildings appear to be easily and quickly erected at small cost; the mineral oil is a powerful illuminant requiring little care in management in catoptric lights, and is inexpensive; moreover, as our experiments show, a higher ratio of illuminating power is obtained from mineral oil in catoptric lights than in any other arrangement. Such a system seems admirably adapted for a young country.

The Department of Marine handled lighthouse construction estimated at under $10,000—Bird Rocks, Cape Norman, Ferolle Point and Cape Ray. Projects on a bigger scale fell to the Department of Public Works.


174.
Plan, Profil et Elevation de la Tour proposée a faire sur la butte de l'Entré
du port de Louisbourg qui servira a éclairer les Vaisseaux et les guider
Verrier)
1 2 3 4 5 6 Toises

Drawing of the Louisbourg lighthouse, the first built in Canada.

The Canadian lighthouse service, in these early post-Confederation years, scarcely compared with that in the British Isles. In Britain, the equivalent of $100,000 was not considered unusual for the construction of an ordinary coastal lighthouse consisting of a stone or masonry tower fitted with dioptric apparatus. A comparable lighthouse in Canada, frequently of frame construction and fitted with catoptric apparatus, could be had for only $8,000. The normal staff for a light station in Britain consisted of three or four uniformed keepers, each of whom had been thoroughly trained; in Canada, by contrast, frequently there was but one keeper per light, assisted by his family. Lightkeeping was not considered a skilled occupation in Canada, hence the preference for simple apparatus in these early years. In the seventies and eighties, the British lighthouse service still used whale oil, costing the equivalent in Canadian currency of 80 or 90 cents per gallon, whereas in Canada coal oil, a superior illuminant for use with catoptric lights, cost but 19 cents per gallon.

In like manner the American system reflected a more costly service, stone towers with several keepers being the rule rather than the exception. Likewise, American lard oil was considerably more expensive than Canadian coal oil. The one disadvantage of coal oil was its inflammable nature. Apart from a score or so of superior lighthouses of masonry construction fitted with lenticular apparatus, the usual Canadian facility was of frame construction with simple reflector apparatus.[27] The very length of the Canadian shore line, both tidewater and inland, particularly with the addition of the Pacific coast on the entry of British Columbia into Confederation in 1871, dictated a measure of economy.

By 1876, the Department of Marine had established six regional agencies responsible for lighthouses, buoys and lightships within their designated limits:

Prince Edward Island Division
Nova Scotia Division
New Brunswick Division
Quebec Division (St. Lawrence below Montreal and Gulf)
Ontario Division (above Montreal)
British Columbia Division[28]

Germane to these enterprising developments in lighting equipment was the institution of the Dominion Lighthouse Depot in a former Prescott starch factory in 1903. Still active in its original premises, the depot by its inventive enterprise has largely rendered Canada independent of overseas suppliers. It has carried out both experimental and manufacturing processes with all types of burners, lanterns, illuminants and lenses tested exhaustively to determine which combinations were best suited to Canadian conditions.

In 1904, a twin development augured well for the future of the Canadian lighthouse service. The Lighthouse Board of Canada, made up of the deputy minister of Marine, the department's chief engineer, the commissioner of lights, the president of the Pilots' Corporation, and a representative of the shipping interests, was instituted by statute with broad terms of reference *to inquire into and report to him* [Minister of Marine and Fisheries] *from time to time, upon all questions relating to the selection of lighthouse sites, the construction and maintenance of lighthouses, fog alarms and all other matters assigned to the Minister of Marine and Fisheries by Section 2 of Chapter 70 of the Revised Statutes of Canada.*

In 1911, the Lighthouse Board was re-organized on a regional basis: the Atlantic division comprising the east coast, Hudson Strait and as far inland as the head of ocean navigation: the Eastern Inland division embracing the region from Montreal to Port Arthur at the head of the lakes, and the Pacific division, including all inland waterways west of Port Arthur (now Thunder Bay) and the Pacific coast.[30] The Lighthouse Board was active until the creation of the Department of Transport in 1936, and indeed has never been officially disbanded.

In 1908, the Department of Marine introduced an elaborate and detailed classification of lighthouses and aids to navigation under no fewer than 19 categories. Devices in the first six categories were fitted with fog alarms and the first of these included a rescue service. Categories 7 to 11 comprised lighthouses without fog alarms, and the final 8 categories were classed as minor stations "where the exclusive services of the keeper are not expected." Of these the last two (18 and 19) consisted of wharf lights and lights attended under contract. Lights in the first category, complete with fog alarms and a rescue service, were Pelee Passage (western end of Lake Erie), Bird Rocks (Gulf of St. Lawrence northeast of the Magdalens), Belle Isle (northeast and southwest ends) and Cape Race. The second category (main seacoast lights with fog alarms) comprised another 14 lighthouses, including such well-known establishments as Point Amour

(Labrador coast, western end, Strait of Belle Isle), Scatarie Island (eastern tip of Cape Breton Island), and Machias Seal Island and Gannet Rock in the Bay of Fundy.

At the outbreak of war in 1914, the total number of lights, principally lighthouses, along the Canadian sea coast and inland waterways (especially the Great Lakes), stood at 1,461 of which 105 were equipped with fog alarms.

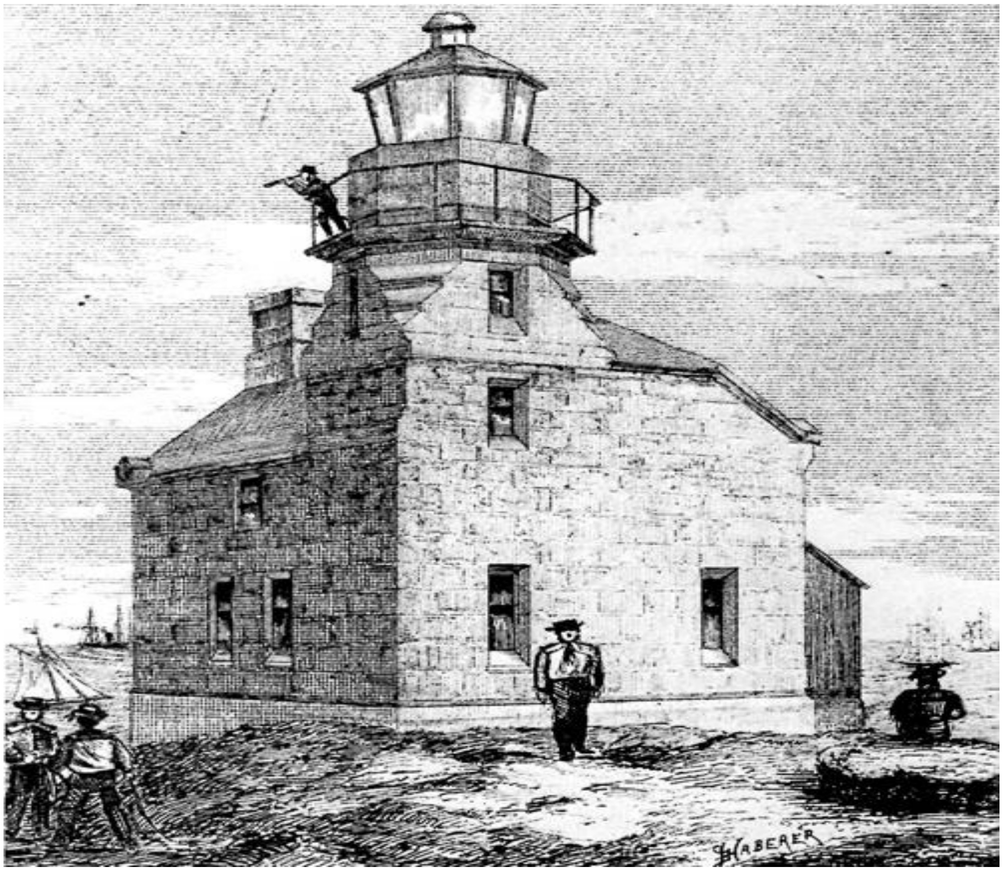
By the spring of 1917, the proliferation of lights along our shores led the department to discontinue a number of minor ones and to improve others by means of superior illuminants and better optics. Based on a 1911 recommendation submitted by the Lighthouse Board, agency boundaries were adjusted to conform more closely to geographical regions. For example, the lighthouses at Belle Isle, Shippegan (northern New Brunswick) and Bird Rocks were placed under the jurisdiction of the Charlottetown agency, whereas Cape Race and Sable Island became the responsibility of Halifax. It should be noted that the principal lighthouses on Newfoundland's shores were a Canadian responsibility, and in earlier times, British. The majority of Newfoundland's lighthouses fell under the jurisdiction, as one would expect, of that colony's Board of Works.

In November 1936, a new federal department fell heir to the Department of Marine dating from Confederation, and to that of Railways and Canals, established in 1879, so combining the function of both. The new Department of Transport assumed responsibility for all marine aids to navigation, embracing the functions of the former commissioner of lights, the chief engineer, and the supervisor of harbour commissions, hitherto within the purlieu of the old Department of Marine. The Navigational Aids Branch terms of reference were broadly defined.

This branch has charge of the construction, repairs, and maintenance of all lighthouses, fog alarms, and other aids to navigation such as lightships, buoys and beacons, and the Sable Island Humane Establishment; the surveying, for registration, and recording of all lands acquired for lighthouse sites; the . . . publications of "List of Lights", three volumes; the issuing of Notices to . . . and the administration of all agency shops and the Dominion Lighthouse Depot at Prescott.[36]

Regional agencies, in general continuing the organization of the old Department of Marine, were established at Halifax, Charlottetown, Saint John, Quebec, Montreal, Prescott, Parry Sound, Victoria and Prince Rupert, with subsidiaries at Port Arthur, Kenora and Amherstburg, each of which operated its own supply depot.[37] In his first annual report, the minister stated that the Canadian Lighthouse Service extended over 52.800 miles of coast line and inland waterways. With the addition of Canada's tenth province to confederation in 1949, all the lighthouses along the Newfoundland coast came under the jurisdiction of the Department of Transport; hitherto, it will be recalled, only landfall and major coastal lights had been under Canadian operation. Top priority was given to the modernization of the Newfoundland facilities to bring them up to the standard pertaining in the rest of the country. To this end, a comprehensive survey of all Newfoundland's lights and fog alarms was at once conducted by department engineers and technicians. St. John's became the scene of a new regional agency serving the same function as those in the rest of Canada.

The Cape Race light was electrified sometime in 1926-27, fed by a Delco generator in a nearby power house. The lenticular apparatus installed in 1907 was retained, however, and to our knowledge at time of writing is still in use. Cape Race is still a manned light station, one of the few on Canada's coasts.



Rose Blanche lighthouse, Newfoundland, with lantern mounted on the roof of a house.

Cape St. Mary's

In 1860, Newfoundland added a third light to her rugged south coast on the lofty promontory known as Cape St. Mary's 325 feet above the sea. Construction was of brick with separate dwellings for the staff. The revolving light on the catoptric principle employing a dozen burners was pronounced by a parliamentary commission to be second to none of its type in the British Isles. Great difficulty was experienced in landing this weighty and delicate apparatus on the rocky shore and hauling it up to the site; nonetheless, the light was ready for service on the night of 20 December 1860. A range of 14 leagues (about 42 miles) was claimed for it in good weather.The old St. Mary's lighthouse has been demolished and replaced with a new structure within recent years.

Cape Ray and Channel Head

Cape Ray, built by the Canadian government in 1871, and Channel Head, erected by Newfoundland in 1875, provided lights complementary to those on St. Paul Island on the Cape Breton side of the strait. Cape Ray was replaced with a new lighthouse in 1960.

Unfortunately information is skimpy on the origins of the Channel Head lighthouse a dozen miles or so southeast of Cape Ray. Construction of a light on this site was recommended by a Captain John Orlebar, R.N., in 1864. It is not clear from information presently on hand whether the Canadian government shared the construction costs or not. In any case, a lighthouse of circular iron construction was completed in 1875 on Channel Head, 40 miles from St. Paul Island.

The Gulf, Northumberland Strait and the Lower St. Lawrence

Access to the gulf is gained by the Strait of Belle Isle and the Cabot Strait to the north and south of Newfoundland respectively. The northern route, an ice-beset channel until well into mid-summer, offers the shorter passage to the British Isles from Quebec and Montreal. In the days of sail Belle Isle was avoided, but with the coming of the steamer by mid-century, the 15- to 20-mile-wide channel between the inhospitable Labrador and Newfoundland coasts attracted more shipping. The advent of the 17- to 18-knot subsidized mail steamer by the year 1905 accelerated this trend. A light did not mark this northerly passage until 1858, and as will be recalled from the previous chapter, only in 1839 had the mariner in the Cabot Strait the benefit of the two lights on

St. Paul Island. Inasmuch as the bulk of the shipping used (and yet does) the southern route, it received the first attention.

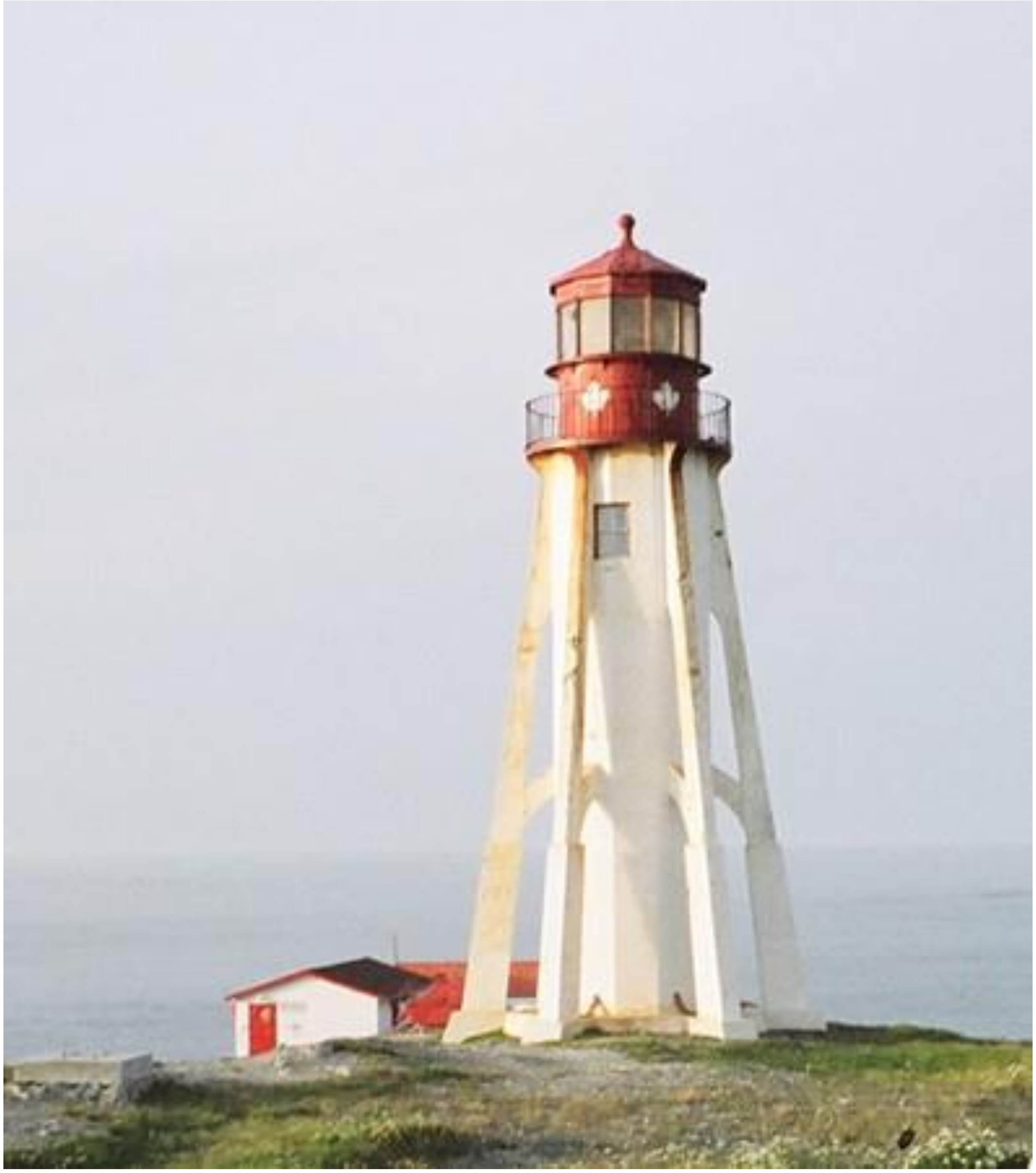
The increased steaming speeds in the latter half of the 19th century demanded a substantial improvement in navigational aids. The president of the veteran Allan Line, the principal steamship company in the Canadian service, put the issue bluntly to the Canadian government in 1869. Among the measures mandatory if Canadian aspirations for a fast mail service operating to the St. Lawrence were to be realized, the following lighthouse projects must have high priority:

Construction at these sites was authorized by an order in council dated 14 January 1870.[1] Short of such an outlay, aggregating $95,000, the chimerical "Canadian Fast Line" would never be feasible.

Belle Isle

Over a period of a half-century, three very important lighthouses were built at the Atlantic entrance to the Strait of Belle Isle on the long tapering island of rugged contour bearing the same name. Undertaken by the Canadian Board of Works, the first of these was constructed on a highly inaccessible site at the south end of Belle isle, 470 feet above the sea. An access road approximately a mile in length had first to be built from the beach to the site. At some points the gradient approached 40 degrees. The cliffs fell away precipitately to the shingle, and no cove or harbour lay within 20 miles. The extreme difficulty experienced in landing and hauling bulky and delicate apparatus under such conditions may be readily appreciated.

The 62-foot stone tower was one of four undertaken simultaneously by the Canadian commissioners of Public Works. The stone was faced externally with firebrick of a light colour. The solidly built circular tower and lantern may still be seen at this lonely spot basically as it was in 1858, although no doubt the firebrick has been renewed and replaced several times. The first light was a fixed one fitted with dioptric apparatus of the 1st Order. In the photograph in Figure 38, the aerial for the radio installations, put up at a much later date, is visible on the left.



Belle Isle, south end, upper lighthouse.

In 1880 this lighthouse was joined by a companion, to be known as the "lower light." As may be seen from Figure 39, the circular lantern was mounted directly on the stone foundation near the edge of a cliff 125 feet above the sea. The lower light was fitted with dioptric apparatus of the 2d Order, to serve in conjunction with the "upper light."

A third lighthouse was built at the north end of Belle Isle in 1905. This 90-foot cylindrical iron tower was later reinforced with concrete and exterior supporting buttresses. The lantern was fitted with dioptric apparatus of the 2d Order, employing a kerosene pressure lamp with a 50-

mm. mantle.[4] This light went into service with the opening of navigation in 1905, in time for the new 17-knot Allan liners *Virginian* and *Victorian,* to be joined during the season of 1906 by the celebrated CPR liners, the *Empress of Britain* and her ill-fated sister, the *Empress of Ireland.* Until the construction of the Triple Island lighthouse on the Pacific coast, the lighthouse on the northern end of Belle Isle was the most northerly in Canada.

All three Belle Isle lighthouses are basically in their original state today, although only the two at the south end of the island are old enough to be of historical interest.

Point Amour

A very fine and impressive lighthouse which was built in 1857 at the western entrance to the Strait of Belle Isle by the Canadian Board of Works is still in good condition today. Situated on the bleak Labrador shore, the Point Amour lighthouse, fully 109 feet in height, is a particularly handsome structure. The slightly tapered circular tower was built of stone, faced with firebrick and surmounted by a round lantern mounted on a circular, railed lantern deck or observation platform. Dioptric apparatus of the 2d Order signifies the importance of this light at the western entrance to the strait.[5]

The Point Amour lighthouse was the scene of a near disaster on the afternoon of 16 September 1889 when a British naval vessel, HMS *Lily,* went ashore in a dense fog. One officer and 30 of the crew made shore. The lightkeeper, Thomas Wyatt, was credited with saving four lives.

Point Amour was one in a series of lighthouses built and maintained by the Canadian government on the Newfoundland and Labrador shore to serve ships on the St. Lawrence route. By the turn of the century Canada maintained a total of 10 light stations in Newfoundland and Labrador.

With the exception of Cape Race, it will be noticed that all these lighthouses were in the Strait of Belle Isle or along the west or gulf coast of Newfoundland.

Bird Rocks

Construction of a lighthouse at the remote mid-gulf Bird Rocks location, hard on the main fairway of shipping inbound from the Cabot Strait, presented one of the most arduous projects attempted in Canadian waters. As the department's chief engineer, John Page, commented in his 1860 report,

> *I beg to remark, that so far as my knowledge of the place and locality goes, it appears to me that the construction of a lighthouse on this islet will be one of the most difficult pieces of work that has ever been undertaken by this Department.*

A notation of the difficulties faced may be had from a glance at Figures 41 and 42. Captain Bayfield, Admiralty hydrographer, had aptly described these islets consisting of soft red sandstone or conglomerate in his survey of the gulf some 30 years previously. The islets presented near-perpendicular cliffs well over 100 feet in height on every hand. Access to the top could be gained in only one or two places, and that with no little difficulty; the device used by the construction engineers. Bayfield concluded by stating that the landing of men and materials could only be effected in the calmest of seas. The largest of the islets, and presumably the one chosen for construction, was 1,800 feet in length by 300 in width, with sheer cliffs some 140 feet above the shingle. The site could be approached only during the settled mid-summer months of July and August. Carried out by contract let by the Department of Public Works, the 51-foot timber and frame tower "of a substantial description thoroughly bolted and fastened similar to the one recently erected on Machias Seal Island" was completed in 1870 and fitted with a powerful 2d Order lenticular light of French make.

Pointe-des-Monts

Based on the 1827 hydrographic survey conducted by Commander H. W. Bayfield, R.N., Anticosti Island, the head of the Gaspé peninsula and the broad reaches of the estuary became desirable sites for lighthouse construction.[12] According to surveys carried out at the behest of the Lower Canada House of Assembly, a light at Pointe-des-Monts on the north shore would benefit vessels both in- and outbound, Anticosti Island, the scene of so many disasters, should have lighthouses established at both its eastern and western extremities. Cap-des-Rosiers, at the head of the Gaspé peninsula, would also be a desirable location, but Bayfield considered that this could be dispensed with if a lighthouse were built at the eastern end (Heath Point) of Anticosti. He offered the further opinion that the Green Island light would have been more effective on the neighbouring Red Islet, but that it was not worthwhile to move it. Bicquette Island was another favourable site, but because of its relative propinquity to Green Island, this project might be considered less urgent.

The crying need for lighthouses on the St. Lawrence in 1828 was further emphasized by Captain Edward Boxer of HMS *Hussar* who had been engaged in survey work along its shores.

I found the greatest want of them, the navigation being so very dangerous, from the currents being so very strong and irregular, and the very great difficulty in getting good observations, the horizon at all times being subject to so great an elevation and depression, and there not being even one in the whole Gulph.

It was truly lamentable Sir, the number of wrecks we saw on the different parts of the coast: . . . for the number of lives lost must be very great, and property incalculable.

Admiral Sir Charles Ogle was yet more emphatic in his description of the hazards encountered along the coast for the want of lights.

The shores of Newfoundland, Anticosti, and the continent, are covered with wrecks, occasioned chiefly by the want of Lighthouses, and the longitude of the places being incorrectly laid down on the charts, and in the books; under these circumstances I venture to recommend to your Excellency, that Lighthouses should be erected on some of the principal points — perhaps on St. Paul's Island, east end of Anticosti, Cape Rosier, and Cape Deamon, which I conceive might be kept up by a Tax levied on all ships entering the St. Lawrence, or the adjacent ports, and would be cheerfully paid by the Shipowners who reap the advantage.

Cap-des-Rosiers

Another interesting lighthouse is the Cap-des-Rosiers lighthouse, completed in 1858 on Gaspé Cape, is the fourth in the handsome series of Public Works lighthouses and today is considered the showpiece of the Quebec agency. One hundred twelve feet in height, its circular lantern housed a 1st Order dioptric light, indicative that the Cap-des-Rosiers installation was considered a major coastal light.

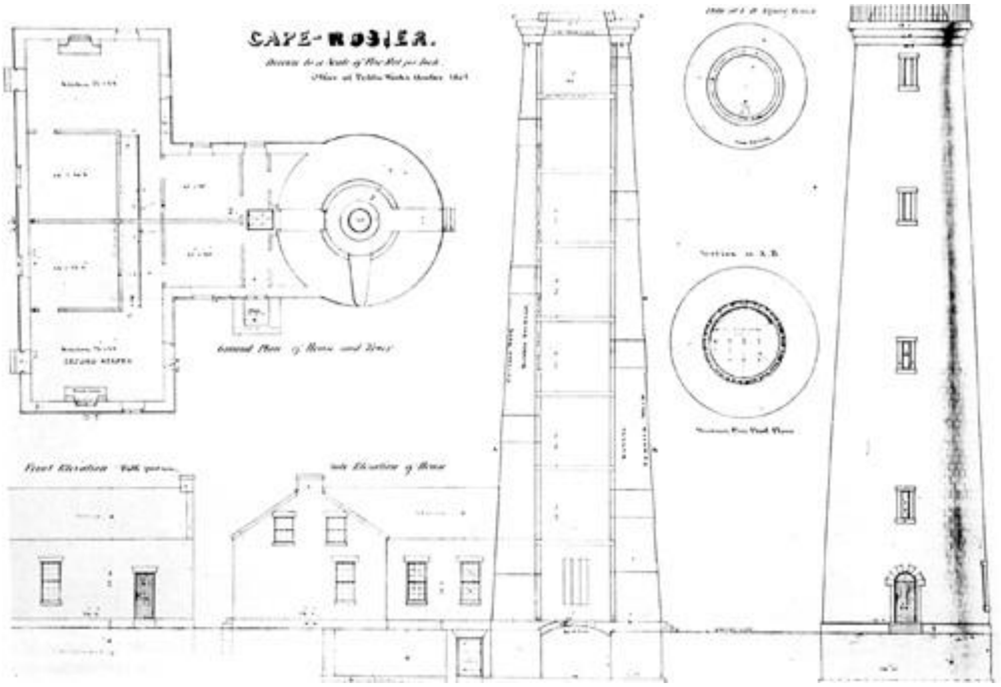
Fortunately the journals of the Canadian legislature record considerable detail on this lighthouse, which is shortly to be removed from service. The foundation, set 50 feet back from the cliff edge, extended 8 feet below the surface. The masonry walls of the 112-foot tower tapered from a thickness of 7 feet 3 inches at the base to an even 3 feet at the top; similarly, the base diameter narrowed from 25-1/2 feet at ground level to only 17 feet at the lantern platform. The tower contained nine storeys including a basement and the light room directly below the lantern. Windows were set at each storey or landing in an alternate pattern.

The masonry called for was of top quality. To consist generally of good sized, flat, well-shaped stones, not less than 5 inches in thickness, laid on their natural and broadest beds in full mortar, properly bonded over and with each other throughout the wall, and to have their inner faces hammered or scrabbled off to a line corresponding to the position they are to occupy in the work, one third of the arch of each course to be laid as headers, that is to say: To have their greatest length extending into the wall, the depth of these headers for the first 30 feet in height of the Tower to be at least 3-1/2 feet, for the next 30 feet in height to be not less than 3 feet in depth, thence upwards they may be from 2 feet 9 inches to 2 feet in depth midway between the headers of the inner face, must be other of a like length extending inwards from the exterior brick facing, especially in the lower 50 feet of the building.

All the brick used in the exterior of the work to be of the best quality of English Fire Brick laid throughout in horizontal courses, except arches in English bond well flushed up at every course with mortar. The brick facings of the Tower as before stated is to be one brick (or 9 inches) in depth, with headers extending into the wall at every fourth or fifth course.

The windows were to be arched with stone, and the door with stone on the inside and brick on the exterior. There were to be two doors to the tower, the outer of which was to be 7 feet by 3 feet. The exterior was to receive three coats of white lead and oil paint; the interior surface of the walls was to be finished with two coats of plaster.

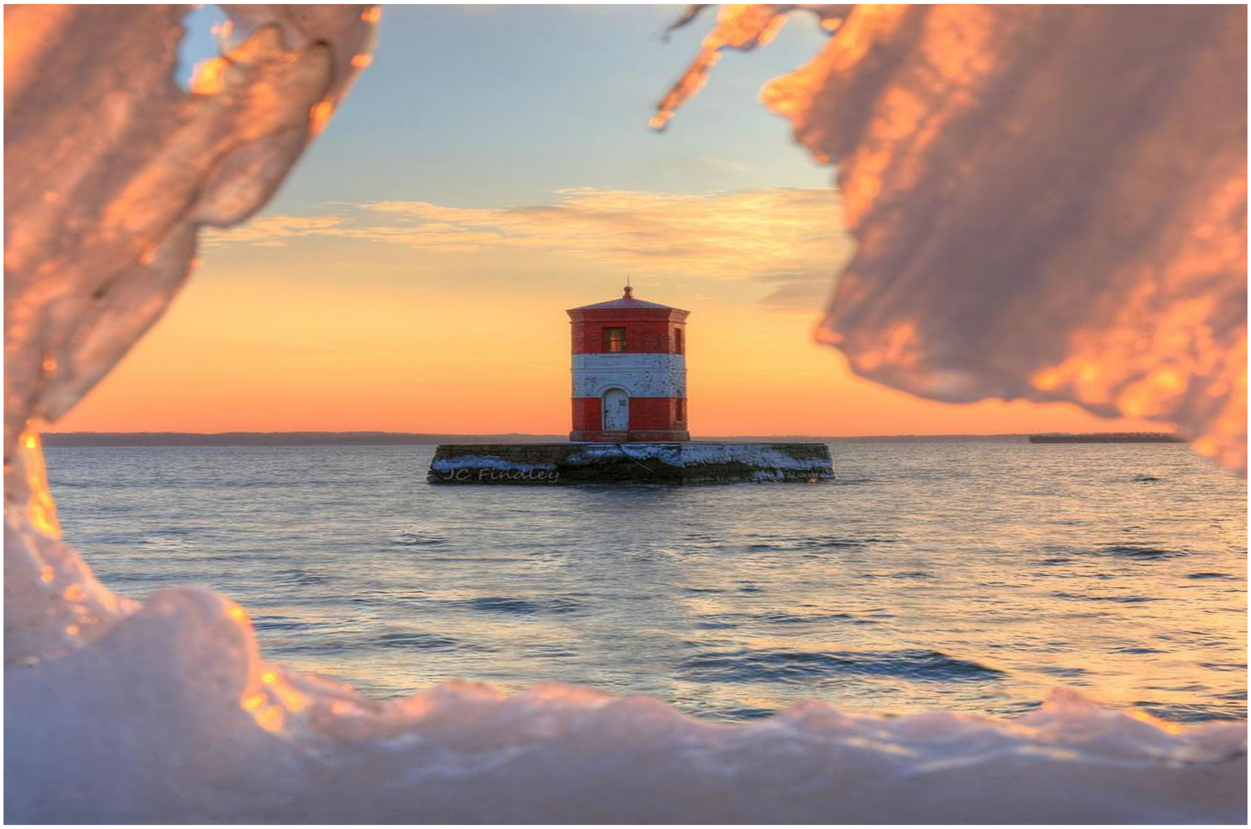
It is not surprising that so carefully and soundly built a structure should have lasted over a century and still be reported in excellent condition. In the near future the Cap-des-Rosiers lighthouse may be offered to the crown for possible preservation, since a light is no longer needed at this point. It is a handsome and impressive structure, somewhat similar in form and design to the series built on Lake Huron and Georgian Bay at the same time. Cap-des-Rosiers is readily accessible by motor, in contrast to Belle Isle or Point Amour, for which the services of a helicopter or supply vessel would be required.



50 Plan drawings of the Cap-des-Rosiers lighthouse on the Gaspé coast.

Light Houses in Sub-Arctic Waters: Hudson Strait and Hudson Bay

Nuclear batteries are nothing new. During Soviet times, around 1,000 so-called RTGs (Radioisotope Thermoelectric Generator) were used to produce electricity for installations in remote areas, like lighthouses on the coast and radio transmitters in mountain areas. Those RTGs had a Strontium-90 (Sr-90) source from where the heat operated a generator providing the electricity.The latest trend is to have unmanned light houses in inhospitable places suchg as the Arctic fuelled bu nuclear power. 132 nuclear-powered lighthouses situated along the north coast in Russia. The closest one was just a few dozen meters from the Norwegian border. These pose dangers of the possible radioactive leaks into the environment and the threat of theft of the radioactive strontium-90 in the unguarded and distantly situated lighthouses.



Craighill Channel lighthouse showing Ice

The lighthouses are located in the area without available electricity sources. They are powered by so-called radio thermoelectric generators, or RTGs, in which the strong strontium source of energy produces heat to power a generator. The generator finally produces electricity to power the lamp in the lighthouse.

Strontium-90 is a waste product generated in a nuclear reactor.

Leaks and theft

Strontium-90 has half-live decay period of 30 years, so the lighthouses can operate without any inspection for many years.The lighthouses is considered to be a threat to the environment's safety. It can take many years before any theft or radioactive leak is noticed, as the lighthouses are not inspected.

Such lighthouses are situated along the coast of the Kola Peninsula, around the White Sea and on Novaya Zemlya. An unknown number of lighthouses are located in Baltic Sea, along the northern sea route in Siberia and around Kamchatka in the Russian Far East.

In the beginning of the 1990s two strontium power sources were found on the coast of the Kola Peninsula not far away from the Norwegian border. The radioactive sources were taken out of the lighthouses. The people who were responsible for shipping the sources did not communicate with those responsible for moving the sources and they remained on the ground until they were accidentally discovered.

In summer 2001 two people received radioactive doses after the attempt to dismantle the lighthouse near Kandalaksha in Murmansk region. They tried to extract the lead from the lighthouse in order to sell it later as scrap metal. They were not aware of the fact that there was a strong radiation source inside the lighthouse.

Lack of information

Last summer the Russian Nuclear Regulatory specialists inspected the lighthouses in Siberia. Inspection revealed terrible facts: most of them were described as in very bad condition. The radiation levels near the lighthouses exceeded the permitted level, which indicates the possibility of radioactive leakage.

But the scariest thing was that the inspectors have not found all the lighthouses they were looking for. There is a slim chance they were stolen and a big chance that the Russian authorities simply lack the full overview of the lighthouses' locations.

At the same time representatives of the International Atomic Energy Agency, or IAEA, were desperately looking for RTG in the mountains north in the former Russian republic of Georgia. The IAEA was afraid the Chechen rebels would use the radioactive source to build a radiological dispersal device, or RDD, such as a "dirty bomb". The Chechen rebels use the area near the Georgian—Russian border for training and hiding.

The American authorities believe terrorists connected with al-Quaida where previously hiding in Georgia.

When used with conventional explosives strontium-90 would cause more serious long-term damage than any ordinary bomb. The blast region would be contaminated with radiation and the population's health will be affected for many years.

The CIA has stated that they found manuals describing the manufacture of RDDs in the al-Quaida caves in Afghanistan.It is quite possible to change the radioactive energy source with other sources for a small price. There are lighthouses along the Norwegian northern coast that are powered with solar batteries. Even during the dark winters they function well due to a good battery capacity.

The authorities of Finnmark county in co-operation with the Russian Northern Fleet changed the energy source in the five lighthouses near the Norwegian border with a solar panel source.

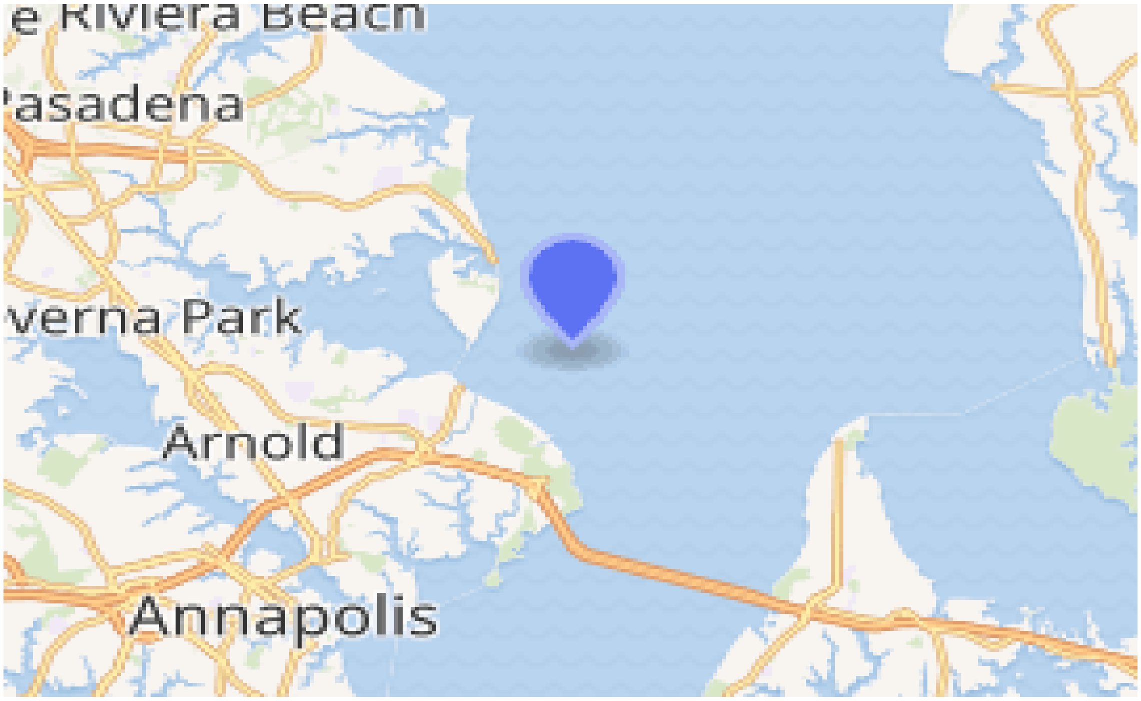
The fear of nuclear terror still haunts the USA, especially after September 11 2001. Since then Americans have expressed a strong wish to assist Russia in securing its nuclear materials. Senator Richard Lugar informed Bellona in his message that he supported the initiative to allocate a part of $400m—designated for securing weapons of mass destruction in Russia—to change the power source on the nuclear-powered lighthouses.

In The USA, the Baltimore Harbor Light, officially Baltimore Light and historically Baltimore Harbor Lighthouse is a privately owned caisson lighthouse in the Chesapeake Bay in Maryland. First lit in 1908, it sits at the mouth of the Magothy River, marking the channel which leads northwest to the opening of the Patapsco River, which then leads into the Baltimore harbor. At the time of its construction, it was the world's tallest caisson lighthouse. In June 2006, Baltimore Light was sold at auction to private owners by the General Services Administration for $260,000; the U.S. Coast Guard maintains rights to operate a light on the structure.

Although a lighthouse had been requested at the site since 1890, it was not until 1904 that construction actually began. In October of that year a violent storm struck the construction site, upturning the caisson and sending it to the bottom of the Bay. The contractor defaulted on the work, and it was not until late in 1905 that construction could resume. The lens was finally installed and the light lit in 1908. It was the last lighthouse to be constructed on the Chesapeake.

In May 1964, the Baltimore Light became the first and only American lighthouse powered by nuclear power, as a test of the SNAP-7B 60 Watt radioisotope thermoelectric generator. One year later the RTG was removed and a conventional electric generator was installed. Currently the lighthouse is solar-powered.

The structure was added to the National Register of Historic Places as Baltimore Light Station on December 2, 2002.



In Canada Commercial navigation came late to the lonely sub-Arctic waters of Hudson Bay and Strait, so long the preserve of the exploratory and the company supply vessel. For this reason, visual aids to navigation have assumed a secondary role to electronic ones.

The lighthouse per se—a solid stone, masonry or wooden tower or simply a house with lantern mounted thereon—has not made its appearance in these northerly latitudes. The transportation of

Baltimore light house, the only nuclear powered one in the USA

stone or lumber to these remote locations would be uneconomical and in any case, the presence of permafrost poses a major foundation problem. In the place of the conventional lighthouse first pole lights, then open-work steel and aluminum towers have performed the function in subpolar regions. Although these visual aids are of scant, if any, historical interest, a brief account is required to complete a descriptive survey across Canada.

Initial Aids in Hudson Strait

The opening of commercial navigation by this northerly route, longer by about 200 miles than the traditional St. Lawrence, hung upon the long-deferred completion of the Hudson Bay Railway to Churchill, a project undertaken in 1911 and completed only in 1931. From this port wheat grown on the Canadian prairies could be shipped to the British Isles during the short two-month navigation season. In premature anticipation of the railway's completion across more than 500 miles of muskeg and rock, the Department of Marine, during the season 1913-14, installed ten AGA-type acetylene pole lights along the shores of Hudson Strait at a cost little short of $69,000. These lights could be left untended during the short navigational season.[1] Although these beacons were mounted only five or six feet above the ground, many were swept away by the frequent gales which ravaged the region. This initial attempt to facilitate passage in the Hudson Strait was not considered a success.

Radio Aids

As mentioned in an earlier context, radio assumed a role of major importance between the two world wars. Radio beacons and direction-finding stations won an early preference over the traditional visual aids in these northern waters. This was in part due to the considerable distances to be covered initially in the Hudson Strait region, and in part because of the few specialized supply vessels using the route, all of which were adequately equipped with radio. In line with this policy, a department memorandum drawn up in January 1928 recommended that the provision of lights and fog signals should await the advent of commercial navigation.[2] The priority given radio aids was illustrated in a departmental letter of the following summer in which the point is made that the installation of a radio direction-finding station at the terminal port of Churchill rendered the employment of a lightkeeper superfluous.[3]

This policy was confirmed by the lighthouse board at a meeting held in December 1929, at which the trend for the future was clearly enunciated by the chief engineer.

I am of opinion that any lights which may be established in Hudson Strait should be electric, and suggest the use of steel towers with lanterns to enclose apparatus and a hut below to contain the machinery which should be in duplicate. I think we should have in mind a visibility of thirty miles.[4]

Herewith was formulated the policy for the future which was carried out over the course of the next four decades with little variation; electric lights powered by diesel generators were to become the order of the day in the far north, as part of the electrification program which followed hard on the Second World War. Most of the earlier lights in the northern regions had been acetylene.

In December 1929 Resolution Island, lying off the southeastern tip of Baffin Island, was chosen as a site for a landfall light to guide shipping in bound to the Hudson Strait. A similar light at the opposite end of the strait was recommended for Carys Swan Nest on Coats Island.[5] Three years later, in 1932, a powerful light was established on Resolution Island on Hatton Headland, 200 feet above the sea, in latitude 61°N.[6] A frame skeleton base supported a square frame lantern.

During the 1932 season, seven lights were established in Hudson Strait; those at Resolution Island and at Cape Hopes Advance were electric, in association with radio stations. In addition, lights were installed at the eastern end of Wales Island and at both ends of Charles Island, lying along the southern shore of the strait. Other lights appeared on the south shore of Nottingham Island, at the western entrance to Hudson Strait and on Coate's Island, in the northernmost reaches of Hudson Bay. With the exception of the electric lights installed on Resolution Island

and Cape Hopes Advance, all these initial light stations employed acetylene lights. The commentary of ships' captains was mixed, some contending that the lights should be of greater power; a range of from 15 to 18 miles was claimed for some.

Experience indicated that steel and aluminum open-work towers of the type installed at Cape Pembroke in 1964 were best suited to the region. At some stations, care of the light devolved upon the radio operators, but at many, the lights were entirely automatic—a trend now becoming rapidly general throughout Canada.

To a considerable degree, this northerly region, bypassing the colourful era of the lighthouse, moved directly into that of electronics. These days, lighthouses are run by machines and remote monitoring. The automatic sensors decide if there is extra moisture in the air, and if so turn on the fog signals. Radio signals are used to communicate with the ships. But when the technology was not so advanced the lighthouses were run by lighthouse keepers.

Selected Inland Waterways

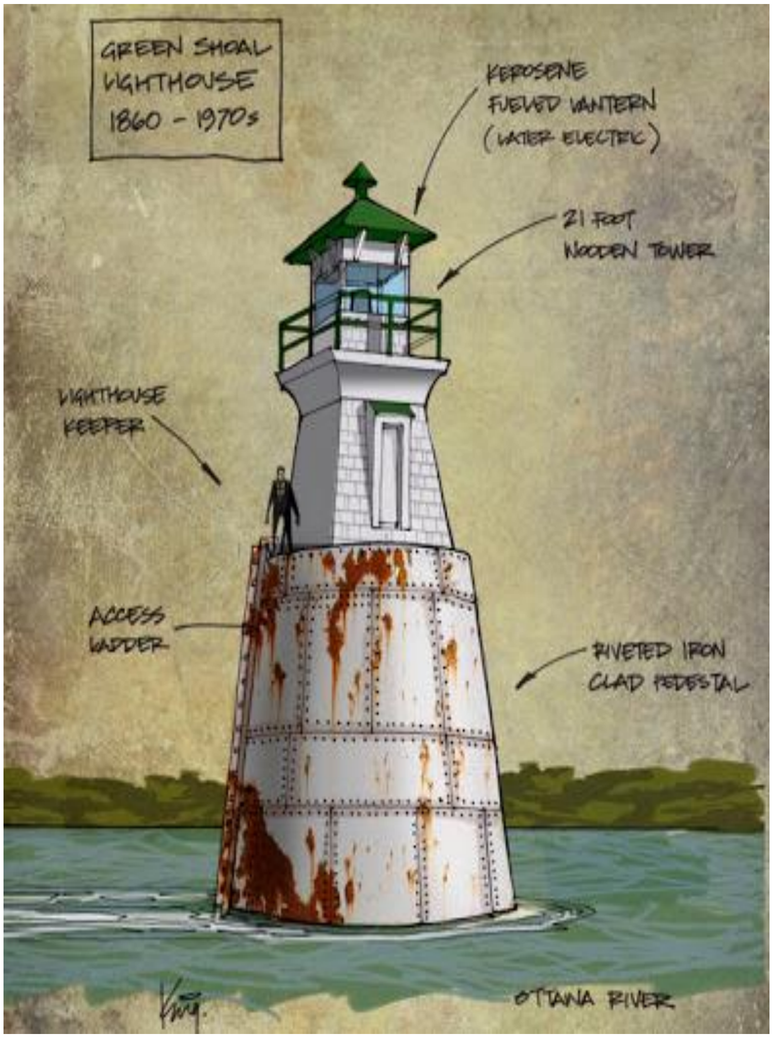
Lighthouses per se, other then on the Great Lakes and the upper St. Lawrence and Ottawa rivers, are rarely encountered on Canada's inland waterways. Mast and pole lights serve this function. Of the few bona fide lighthouses in this vast inland region of innumerable freshwater lakes and their connecting river systems, few are old enough or distinctive enough to be of historical interest; Black Bear Island lighthouse on Lake Winnipeg and several frame structures on the Ottawa River are possible exceptions.

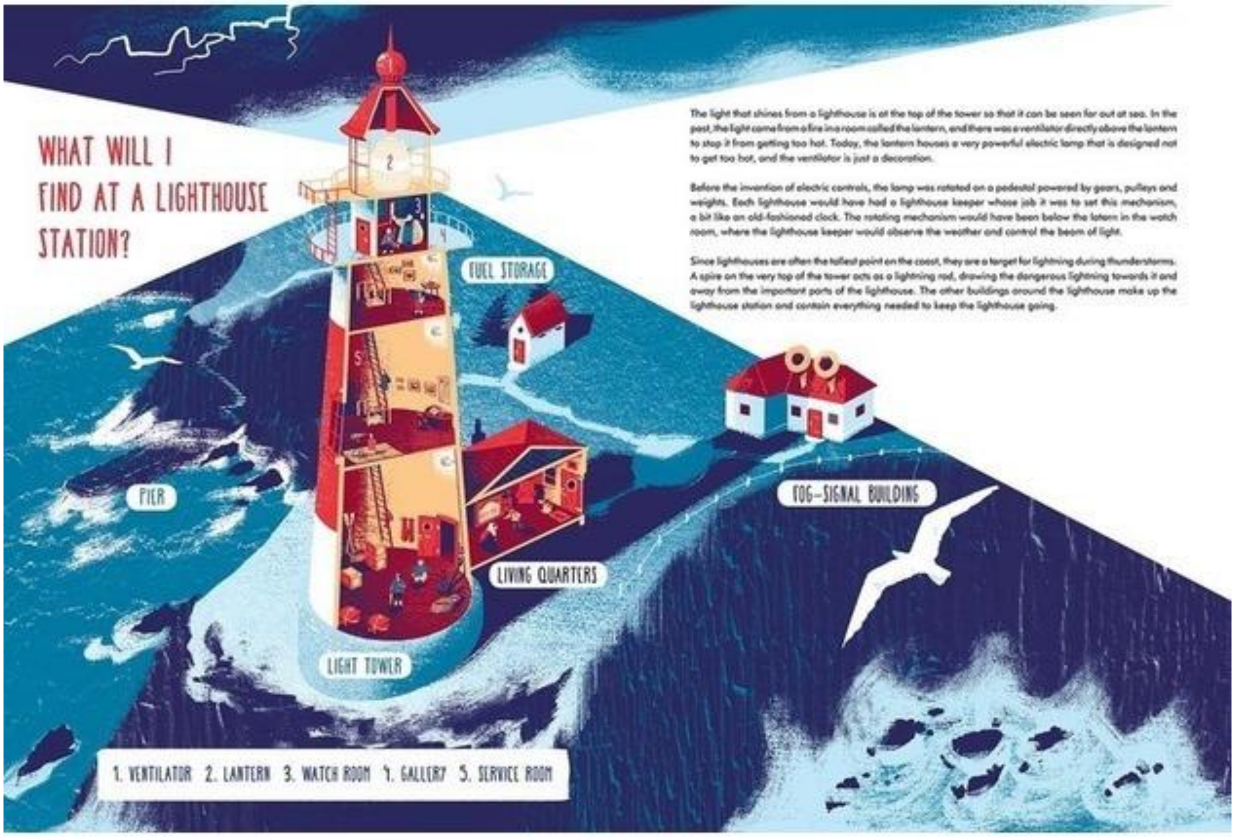
Ottawa River

The first lighthouses to be built on the Ottawa were at Green Shoal opposite Templeton, lit for the first time on 27 October 1860, and at Point Valois, which went into service on the sixth of the same month. The latter was a floating light mounted on an iron barge which was discontinued a number of years ago. The reflector apparatus used employed flat-wick coal oil lamps. The Green Shoal structure, now over a century old, consists of a square tower 21 feet in height from base to vane, its timbers and lumber of oak and pine. The total estimate for the project came to $3,985.

On the upper Ottawa, three surviving structures claim our attention, one of which is of rather unusual height. Both follow the familiar configuration of square towers, with sloping sides (pepper-pot style) and square wooden lanterns, and both first saw service in 1873. One was built on Morris Island at the lower end of broad and placid Lake Chats, and the other at Deep River

Islet , a 24-foot square frame tower with a pronounced slope to its shingled sides, located above Allumette Island on the upper Ottawa.[3]


GREEN SHOAL LIGHTHOUSE 1860 - 1970s
KEROSENE FUELED LANTERN (LATER ELECTRIC)
21 FOOT WOODEN TOWER
LIGHTHOUSE KEEPER
ACCESS LADDER
RIVETED IRON CLAD PEDESTAL
OTTAWA RIVER

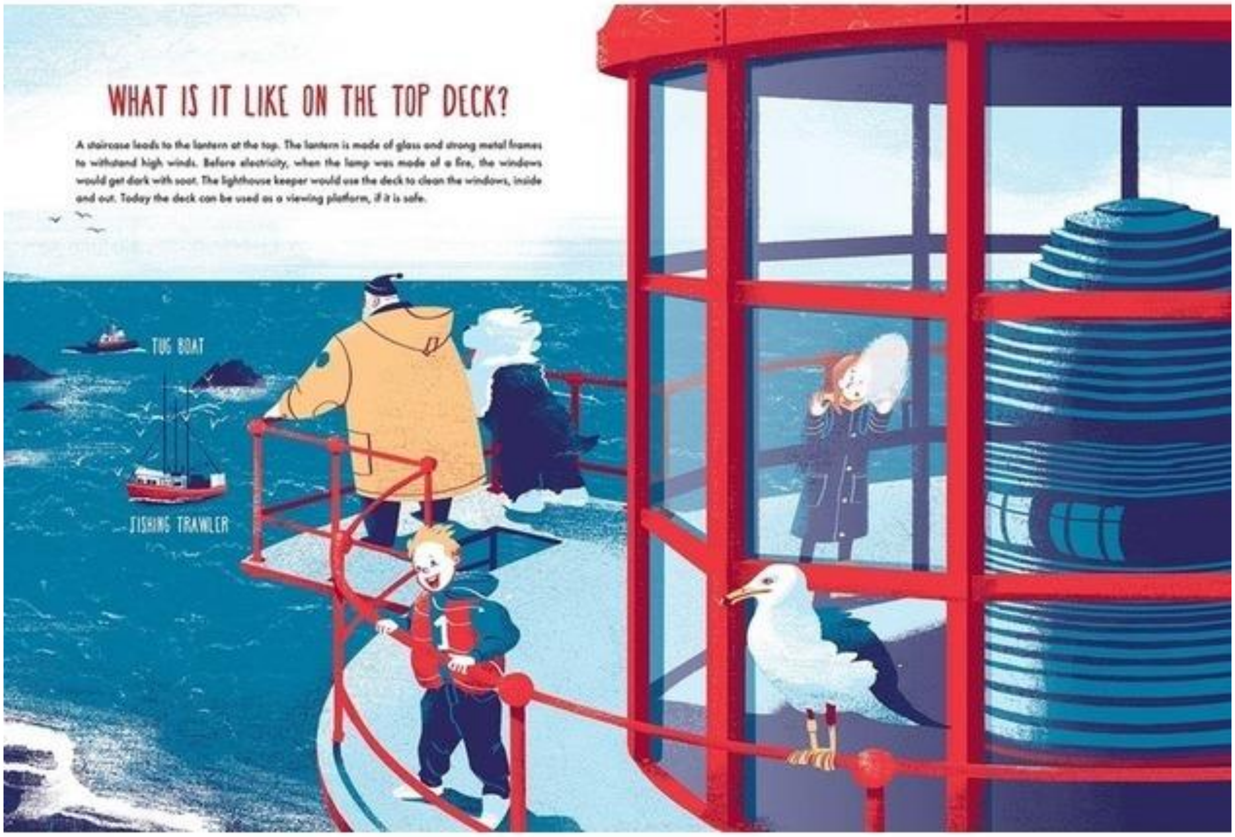


WHAT WILL I FIND AT A LIGHTHOUSE STATION?

The light that shines from a lighthouse is at the top of the tower so that it can be seen far out at sea. In the past, the light came from a fire in a room called the lantern, and there was a ventilator directly above the lantern to stop it from getting too hot. Today, the lantern houses a very powerful electric lamp that is designed not to get too hot, and the ventilator is just a decoration.

Before the invention of electric controls, the lamp was rotated on a pedestal powered by gears, pulleys and weights. Each lighthouse would have had a lighthouse keeper whose job it was to set this mechanism, a bit like an old-fashioned clock. The rotating mechanism would have been below the latern in the watch room, where the lighthouse keeper would observe the weather and control the beam of light.

Since lighthouses are often the tallest point on the coast, they are a target for lightning during thunderstorms. A spire on the very top of the tower acts as a lightning rod, drawing the dangerous lightning towards it and away from the important parts of the lighthouse. The other buildings around the lighthouse make up the lighthouse station and contain everything needed to keep the lighthouse going.



WHAT IS IT LIKE ON THE TOP DECK?

A staircase leads to the lantern at the top. The lantern is made of glass and strong metal frames to withstand high winds. Before electricity, when the lamp was made of a fire, the windows would get dark with soot. The lighthouse keeper would use the deck to clean the windows, inside and out. Today the deck can be used as a viewing platform, if it is safe.

Radslaw Pujan pic

CHAPTER V

FUTURE LIGHT HOUSES

Costa Concordia was a cruise ship operated by Costa Crociere. She was the first of the Concordia-class cruise ships, followed by similar ships Costa Serena, Costa Pacifica, Costa Favolosa and Costa Fascinosa, and Carnival Splendor built for Carnival Cruise Line. When the 114,137 gross tonnage (GT) Costa Concordia and her sister ships entered service, they were among the largest ships built in Italy until the construction of the 130,000 GT Dream-class cruise ships.

On 13 January 2012 at 21:45, Costa Concordia struck a rock in the Tyrrhenian Sea just off the eastern shore of Isola del Giglio. This tore open a 50 m (160 ft) gash on the port side of her hull, which soon flooded parts of the engine room, cutting power from the engines and ship services. With water flooding in and the ship listing, she drifted back towards the island and grounded near shore, then rolled onto her starboard side, lying in an unsteady position on a rocky underwater ledge.

The evacuation of Costa Concordia took over six hours, and of the 3,229 passengers and 1,023 crew known to have been aboard, 32 died. Francesco Schettino, the ship's captain at that time, was subsequently found guilty of manslaughter, causing a maritime accident, and abandoning his ship. The wreck was salvaged three years after the incident and then towed to the port of Genoa, where scrapping operations began.

Costa Concordia was ordered in 2004 by Carnival Corporation from Fincantieri and built in the Sestri Ponente yard in Genoa, as yard number 6122. At the vessel's launch at Sestri Ponente on 2 September 2005, the champagne bottle, released by model Eva Herzigová, failed to break when swung against the hull the first time, an inauspicious omen in maritime superstition. The ship was delivered to Costa on 30 June 2006. It cost €450 million (£372 million, US$570 million) to build. The name Concordia was intended to express the wish for "continuing harmony, unity, and peace between European nations."

Costa Concordia was 290.20 metres (952 ft 1 in) long, had a beam of 35.50 m (116.5 ft) and drew 8.20 m (26.9 ft) of water. She had a Diesel-electric power plant consisting of six 12-cylinder Wärtsilä 12V46C four-stroke medium-speed Diesel generating sets with a combined output of 76.6 MW (102,780 hp).[12] These main generators provided power for all shipboard consumers from propulsion motors to hotel functions such as lighting and air conditioning. The ship was propelled by two 21-megawatt electric motors coupled to fixed-pitch propellers. Her design service speed was 19.6 knots (36 km/h; 23 mph),[6] but during sea trials, she achieved a speed of 23 knots (43 km/h; 26 mph).

Amenities: Costa Concordia was outfitted with approximately 1,500 cabins; 505 with private balconies, and 55 with direct access to the Samsara Spa, which were considered Spa staterooms; 58 suites had private balconies and 12 had direct access to the spa. Costa Concordia had one of the world's largest exercise facility areas at sea, the Samsara Spa, a two-level, 6,000 m^2 (64,600 sq ft) fitness center, with gym, a thalassotherapy pool, sauna, Turkish bath and a solarium. The ship had four swimming pools, two with retractable roofs, five jacuzzis, five spas, and a poolside movie theatre on the main pool deck.[15] There were also five on-board restaurants, with Club Concordia and Samsara taking reservations-only dining. There were thirteen bars, including a cigar and cognac bar and a coffee and chocolate bar. Entertainment options included a three-level theatre, casino, a futuristic disco, a children's area equipped with video games and a basketball court. She also had aboard a Grand Prix motor racing simulator and an internet café.

On 22 November 2008, Costa Concordia suffered damage to her bow when high winds over the Sicilian city of Palermo pushed the ship against its dock. There were no injuries and repairs started soon after.[16][17][18]

2012 grounding and partial sinking

On 13 January 2012, under the command of Captain Francesco Schettino, the Costa Concordia departed Civitavecchia, the port for Rome, Italy, on a 7-night cruise. At 21:45 local time (UTC+1), in calm seas and overcast weather, she collided with a rock off Isola del Giglio (42°21′55″N 10°55′17″E), on the western coast of Italy about 100 km (62 mi) northwest of Rome. A 53-metre (174 ft) long gash was made in the port-side hull, along 3 compartments of the engine room (deck 0); resulting in power losses, leading to a loss of propulsion and loss of electrical systems, which crippled the ship. Taking on water, the vessel listed to the port side. Twenty-four minutes later, strong winds pushed the vessel back to Giglio Island, where she grounded 500 m (550 yd) north of the village of Giglio Porto, resting on her starboard side in shallow waters, with most of her starboard side underwater.

Almost half of the ship remained above water, but it was in danger of sinking completely into a trough 70 metres (230 ft) deep. Despite the gradual sinking of the ship, its complete loss of power, and its proximity to shore in calm seas, an order to abandon ship was not issued until over an hour after the initial impact. Although international maritime law requires all passengers to be evacuated within 30 minutes of an order to abandon ship, the evacuation of Costa Concordia took over six hours. At the time, she was carrying 3,206 passengers and 1,023 crew members. The accident resulted in 32 fatalities. The body of the last missing person, Indian crew member Russel Rebello, was recovered on 3 November 2014.

Salvage

Costa Concordia salvage operation in progress

An initial assessment by salvage expert company Smit International estimated that the removal of Costa Concordia and her 2,380 tonnes of fuel could take up to 10 months. Smit advised that the ship had been damaged beyond the hope of economical repair and recommended it be written off as a constructive total loss. Smit was soon contracted to initially remove only Concordia's fuel.

During the fuel removal operation, Smit reported that the ship had shifted 60 cm (24 in) in the three weeks since her grounding, but that there was no immediate prospect of her breaking up or sinking deeper. Removal of the fuel from the various fuel tanks distributed throughout the ship was completed in March 2012, later than Smit's initial estimates. This cleared the way to arrange for the ultimate salvaging and scrapping of the ship.

On 17 September 2013, Costa Concordia was brought to a vertical position through a parbuckling procedure. The cost for salvaging the ship increased to $799 million. In addition, the ship had suffered severe hull deformations in two places. Titan Salvage, the company directing the salvage operations, estimated that the next phase of the salvage operation would be completed by early-to-mid-2014. After this "floating" operation, the ship would be towed to a salvage yard on the Italian mainland for scrapping or "breaking".[37]

On 14 July 2014, work commenced to refloat Costa Concordia in preparation for towing. At this point, the costs had risen to €1 billion. Including tow cost, €100 million for the ship to be broken up for scrap and the cost of repairing damage to Giglio island, the estimated final cost was expected to be €1.5 billion ($2 billion). On 23 July, having been refloated, the ship commenced its final journey under tow at a speed of 2 knots (4 km/h; 2 mph), with a 14-ship escort, to be scrapped in Genoa. It arrived at port on 27 July, after a four-day journey. It was moored to a seawall at the port, awaiting dismantling processes. On 11 May 2015, following initial dismantling, but still kept afloat by the salvage sponsons, the hull was towed 10 miles (16 km) to the Superbacino dock in Genoa for removal of the upper decks. The last of the sponsons were removed in August 2016 and the hull was taken in to a drydock on 1 September for final dismantling. Scrapping of the ship was completed on 7 July 2017.

What does the future hold for our lighthouses?

There can be few more familiar sights when than cruising along the British coastline on a night passage and ticking off the various marks and lights as they pass by, Beachy Head, Selsey Bill, Portland Bill, Eddystone, these names themselves evoke nostalgia for anyone who loves the sea.

The thought of these marks ever disappearing might seem unthinkable, yet the General Lighthouse Authorities (GLA) , who maintain our Aids to Navigation, is mooting the idea of discontinuing a number of lighthouses and Aids to Navigation as part of their five yearly review.

The GLAs claim that as navigational technology advances, reliance on the traditional system of lighthouses around the coast diminishes. With the exception of leading lights and PEL sector lights, landfall lights and passing lights are now considered less important and their primary function is for confirmation of position and spatial awareness.

The GLAs reason that 'traditional' aids to navigation can be regarded as a secondary but complementary system to the primary navigation system of GNSS.

New technology

Doubtless, there are many out there with a lead line and a hand bearing compass who aren't too happy about that, yet perhaps they have a point: With the vast amounts of technology around at present in the form of GPS, radar, AIS, there's plenty out there, particularly if you are a large commercial vessel.Herein lies the dilemma, however, the recreational boater may not carry half of these gadgets and it's perfectly plausible that you may not have any of them on board.After all, the basis of the RYA Yachtmaster Offshore syllabus has always been that you need to learn the basics of navigation, (estimated positions, running fixes and bearings), in order to use the technology out there properly.So the requirements of the commercial vessel compared to the recreational boater might vary hugely as we are often exploring corners of the coast that are untouched by commercial vessels.

Commercial shipping

The GLAs have used AIS tracking analysis to determine the volume type, patterns and track of vessels in order to inform their reviews and to carry out their analysis on the necessity for certain navigational aids.

Recreational boaters for the most part do not carry AIS transponders and are therefore not a part of that analysis, but on the other hand, we don't pay Light Dues for the various Aids to Navigation, which vessels in the commercial sector do.So, what is the RYA's view on this, given that famous lighthouses such as Beachy Head, Hartland Point, Skokholm Light and Orfordness lighthouse are all earmarked to be discontinued, albeit with alterations in the ranges of other adjacent lights and the addition of other markers to offset this.

RYA View

The RYA's Stuart Carruthers has been chewing over the issue:. “On the one hand, there is little doubt that the Aids to Navigation are being reviewed largely with the needs of commercial vessels in mind.

"This is understandable as it is clear that most physical Aids to Navigation are positioned to mark major hazards and high density traffic schemes and are of far less significance for leisure craft navigation.

"In addition to this, recreational boaters are not confined to established shipping routes and are more than capable of navigating in and exploring areas that are pretty much unmarked anyway, in fact, this is a big part of the skills that we teach through our training syllabus."

The RYA still believes that there is no case for recreational boaters to pay non-periodic light dues on vessels below 20m LOA and has worded its response to the GLA review with that uppermost in its mind.Perhaps of greatest concern, however, is the proposed over reliance on emerging technology such as AIS to provide navigational warnings; currently, this technology is not widely fitted to small craft and the Class B ‘recreational’ transceivers are unlikely to be able to process these warnings."It's a tricky issue and one to keep an eye on in the future" Stuart concluded: "At present, these changes won't unduly affect the recreational boater, but we will be looking at future developments and trying to ensure we don't end up in a situation where recreational boaters are over reliant on expensive technology."

The spring of 2016 saw the publication of the 500-plus-page “Brilliant Beacons: A History of the American Lighthouse” by Marblehead resident Eric Jay Dolin. Dolin delves deeply into the technological evolution of these navigational lifesavers and the lives of the men and women who kept them lit through time and tempests.

September marks the 300th anniversary of Boston Light on Little Brewster Island. HARRISON HILL FOR THE BOSTON GLOBE/FILE

Many timeswe think we know lighthouses. Images of iconic coastal beacons are everywhere, from stirring (if hyperbolic) motivational posters, to sunset photos on Facebook, to the Cape Cod Potato Chips logo. We see them on sailing trips, or days at the beach, or long drives along the coast.

But recent events are shining a new light on these seaside sentinels, only two-thirds of which still function as navigational aids. Some lighthouses are passing into private hands. Some have become offshore inns for short-term swashbucklers. More ominously, even celebrated landmarks are being threatened by storms related to climate change, and could be at risk of destruction after centuries of guiding sailors to safety.

Yet lighthouses continue to inspire photographers, poets, and history buffs; this spring two new books about lighthouses have been released. As the area gears up for the 300th anniversary in September of Boston Light, the country's oldest lighthouse station in the Boston Harbor Islands National and State Park, one writer — lighthouse historian Jeremy D'Entremont — cautions that a number of the estimated 800 lighthouses remaining in the country (of about 1,000 original lighthouse stations) are in dire need of upkeep.In particular, he points to aging offshore lighthouses, those stalwart towers perched on rocky ledges or small islands, posing logistical challenges for even the most devoted preservationists.

"One of the hardest things is getting people to realize that lighthouses need help and money," said D'Entremont, the New Hampshire-based author of more than a dozen books on lighthouses and maritime history, including "Boston Light: Three Centuries of History." "People don't realize the federal government is no longer taking care of all these structures. It's falling to nonprofits, where the lack of money is a constant struggle."[1]

Future Light Houses: matterbetter_dev initiated the Concordia Lighthouse Competition for architectural students and young professionals. Participants were asked to redefine a contemporary lighthouse typology and take into consideration advances in technology, development of sustainable systems and its metaphorical value which has made it one of the most inspiring structures in the world. Lighthouse design should become a tribute to the Costa Concordia Disaster and highlight the vulnerable borders between the elements of Land and Sea, Sky and Ground, Light and Darkness. Even today when global positioning systems diminish the role of the lighthouses, they still play and important role and are inalienable parts of the marine navigation tradition.

matterbetter_dev has received in total 282 submissions. International Jury Board, which consisted from Emmanuelle Moureaux, Eric Schuldenfrei, Cristina Cassandra Murphy and Daria

Polozkova, has selected the Winners and Honorable Mentions of the Concordia Lighthouse Competition.

Winner 1st Place

292292 / Gwizdala Andrzej / Adrien Mans/Poland/ Belgium

Jury Comment:

Very interesting concept with beautiful expression. The idea of a "dispersed" lighthouse composed of "lines" totally redefines the typology of lighthouse, which is usually built as a massive and solid architecture. Composed of thin lines whom density increases growing toward the sea, the structure appears beautifully during the day. At night, all the lines light up and fragments of thin lights connect the sea and the coast in a dramatic yet poetic way. The idea creates more than a lighthouse, it creates a "lightscape". - Emmanuelle Moureaux

The intermediate scale discussed in this proposal makes sense. Traditionally, the cylindrical shape is inaccessible from its immediate context: the rigid verticality and scale find no other proximate reference and the connection with the ground is brutal, essential, and un- ceremonial. This projects takes over this aspect and transforms the isolated, disconnected, and anonymous character of the lighthouse domain into a ceremonial, public, and unique environment. In this proposal, it is important to pay attention to the temporal relation between what had happened and what can still become: the structure reaches out to the 'heart of the drama' and looks back toward the inhabitants of the island. This project is a secure hand that leads the visitor to confront and commemorate the past event and, at the same time, provides the opportunity to give that same place a new social significance. - Cristina C. Murphy

Winner 2nd Place

222812 / Lý Thanh Hoàng Phúc, Nguyễn Xuân Trang, Trịnh Tiến Vinh , Nguyễn Đình Anh Huy, Đỗ Thị Vành Khuyên / Vietnam

Jury Comment:

The Silent Compass proposal is clear and accurate in its presentation. The design sheet initiates a consistent investigation of the architectural structure and serves as a good visual explanation of the theoretical narrative behind the creation of the eventual design. The lighthouse has a fluent and harmonious feel and is a pleasure for the eye. I love how the path leading to the lighthouse is incorporated in the natural landscape, almost invisible among the rocky setting and yet edgy and clearly present at the same time. The lighthouse changing character during the course of the day makes it a lively architectural structure with amazing power to transform in accordance with the surrounding natural environment. This transformation of visual appeal during the course of day is subtle and yet very clear. The spatial potential of the building has been used in such a way to include a big variety of functions without compromising its light and translucent character.

The design succeeds in preserving traditional architectural typology redefining the lighthouse by abstracting it to its symbolic qualities. Proposed landmark becomes a symbol of the terrible event without evoking an oppressing presence, becoming rather a reminder for the future generations. This is a very important issue. One must not forget that the enormous shipwreck of Concordia and the tragic emotions it provoked were a part of this island for a very long time. This obligatory confrontation with tragedy was a daily routine for the local habitants of Isla Giglio for many years. I find this calm and elegant lighthouse to be a matter of honor for the people who've lost their loved ones, and respect for the feelings, negative emotions and patience of the local community, which was confronted with this negative situation, and everything it encompassed, on a daily basis, for years. The Silent Compass pays homage to the victims, the people of the island, its visitors, nature and landscape in a very elegant way. It evokes a healing process through its transformative character, provides a comfortable place for contemplation and memory, opens an amazing panoramic view on the landscape during the whole course of ascension and descent. - Daria Polozkova

This project is dense with significance as it sets the right questions forward: what is a lighthouse today and how can this trigger awareness of the surrounding? These quests are, in themselves, sustainable. The proposal is well illustrated and, simply, describes functionality on a 24 hours cycle. Aesthetically unique, the proposal exhibits an interesting transformation between the traditional image of lighthouse and a more adaptive design which includes various programs and responds to diverse contemporary purposes. - Cristina C. Murphy

Winner – 3rd Place

240820 / Matteis Valentino Danilo, Daniele Dimitris Michele / Italy

Jury Comment:

Certainly a new expression and interesting spatial experience. The idea considers the lighthouse not as a building but as an experience through exploration, a real story beginning from the approach. The long path goes slowly under the sea, then connects to a large horizontal water circle floating on the sea where visitors can rest with feet in the water. The light-beam glowing vertically from the center of circle connecting the sea and the sky, is strong and dramatic. Only the light appears in the landscape (everything is hidden or horizontal) instead of the usual vertical architecture. - Emmanuelle Moureaux

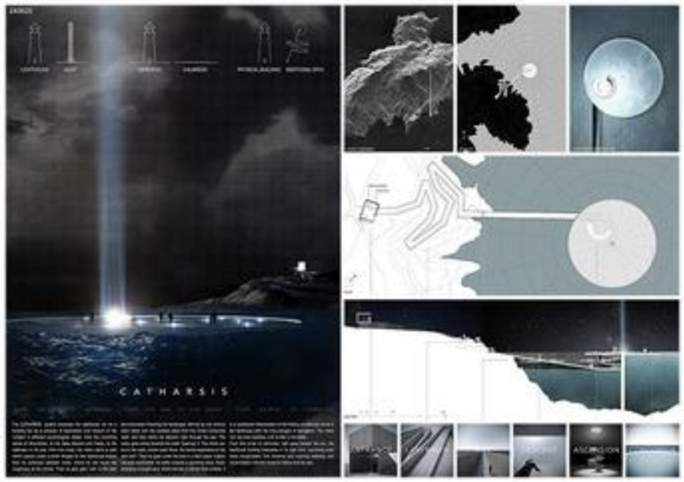
The Catharis proposal fully justifies its name. The visual presentation is comprehensible and pure, evoking a modest mystical flair. The structure of the architectural composition is delicate and very strong at the same time, based on so many direct and indirect oppositions. The general perception of the design translates an inspiring dialectics between the futuristic appeal of the structure and its simple forms and archetypical sculptural gestures. The contrast of initial forms, the distortion between the intricate labyrinth and the round shape of main structure, the opposition of straight descent and twisted ascension, and duality of the restricted horizontal line connecting the mainland with the sea followed by an unlimited vertical one leading towards the sky, has an amazing symbolic beauty. The variety of emotional experiences the visitor adjoins and is forced to go through is reminiscent of a process of pure meditation, compressed in material architectural form. The design does not only evoke a general psychological state of meditation, but also succeeds in encompassing a strong site specific and contextual narrative. The memory of the Costa Concordia tragedy is brilliantly recalled through an experience which unfolds during the visitors’ journey to the lighthouse. This architecture resembles the course of ships’ sinking, the emotional state of the human body struggling to survive, and the symbolic journey of the human soul of those who didn’t. This design is crucial in accentuating the duality of physical chaos and eternal harmony. The Catharis lighthouse is a true memorial and a dignified architectural composition. - Daria Polozkova

GWIZDALA ANDRZEJ, MANS Adrien

FIRST PRIZE

Lý Thanh Hoàng Phúc, Đỗ Thị Vành Khuyên, Nguyễn Đình Anh Huy, Trịnh Tiến Vinh , Nguyễn Xuân Trang

SECOND PRIZE



Matteis Valentino Danilo, Daniele Dimitris Michele

THIRD PRIZENEWSTHIRD PRIZE

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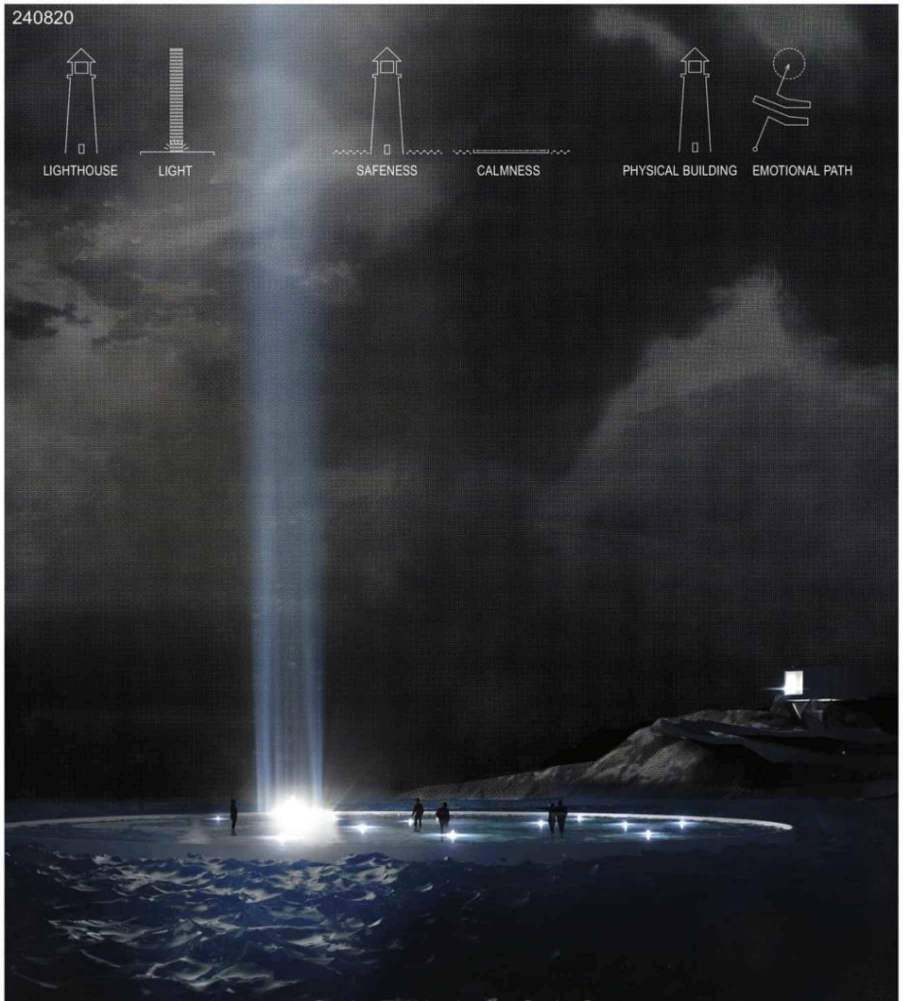
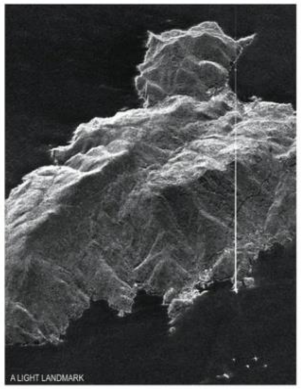


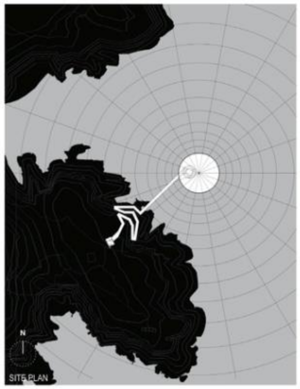
C A T H A R S I S

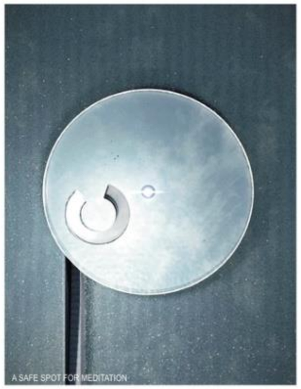
from tension to safeness | from the sea to the coast | from pathos to catharsis

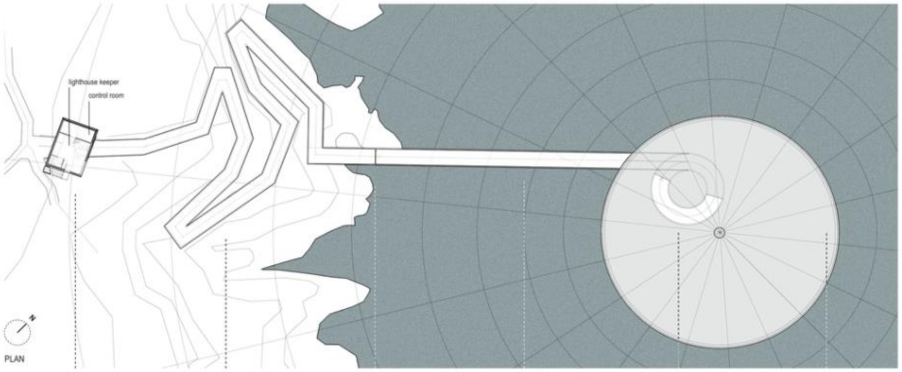
The CATHARSIS project proposes the lighthouse not as a building but as a process of exploration and recount of the incident in different psychological states: from the unsettling sense of strandness, to the deep descent and finally, to the safeness in the sea. From the coast, the visitor starts a path which passes under a small refugee for the lighthouse-keeper, then he continues between rocks, where he can touch the roughness of the stones. Then he gets gets "lost" in the path that articulates following the landscape, defined by two vertical walls made with the oxidized steel from the Costa Concordia itself, and then starts his descent right through the sea. The ramp goes slowly towards the water "opening" it. The visitor can touch the walls, where water flows: the tactile experience of the sea itself. Then he goes under the sea in a dark place: slightly lost and disoriented, he walks towards a spiralling ramp, finally emerging in a safe spot, where the sea is calmer than outside. It is a symbolical interpretation of the feeling of safeness found in the lighthouse after the long struggle of navigation. The visitor can rest and meditate, with its feet in the water.

From this circle of calmness, light goes toward the sky, the traditional building dissipates in its light form, becoming even more recognizable from distance and inspiring safeness and reconciliation with the forces of nature and the sea.

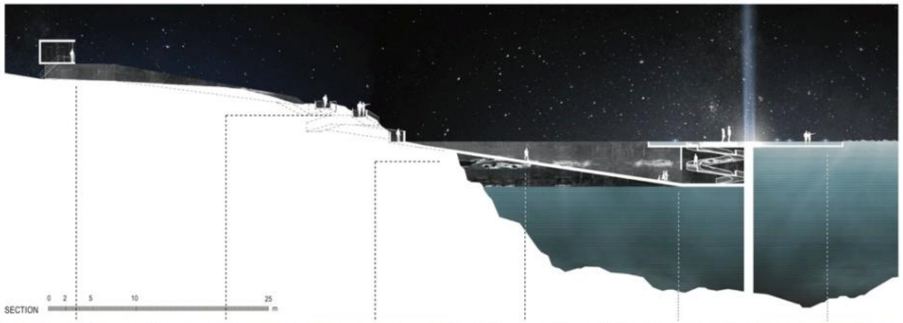

A LIGHT LANDMARK


SITE PLAN


A SAFE SPOT FOR MEDITATION



PLAN


SECTION

ENTRANCE

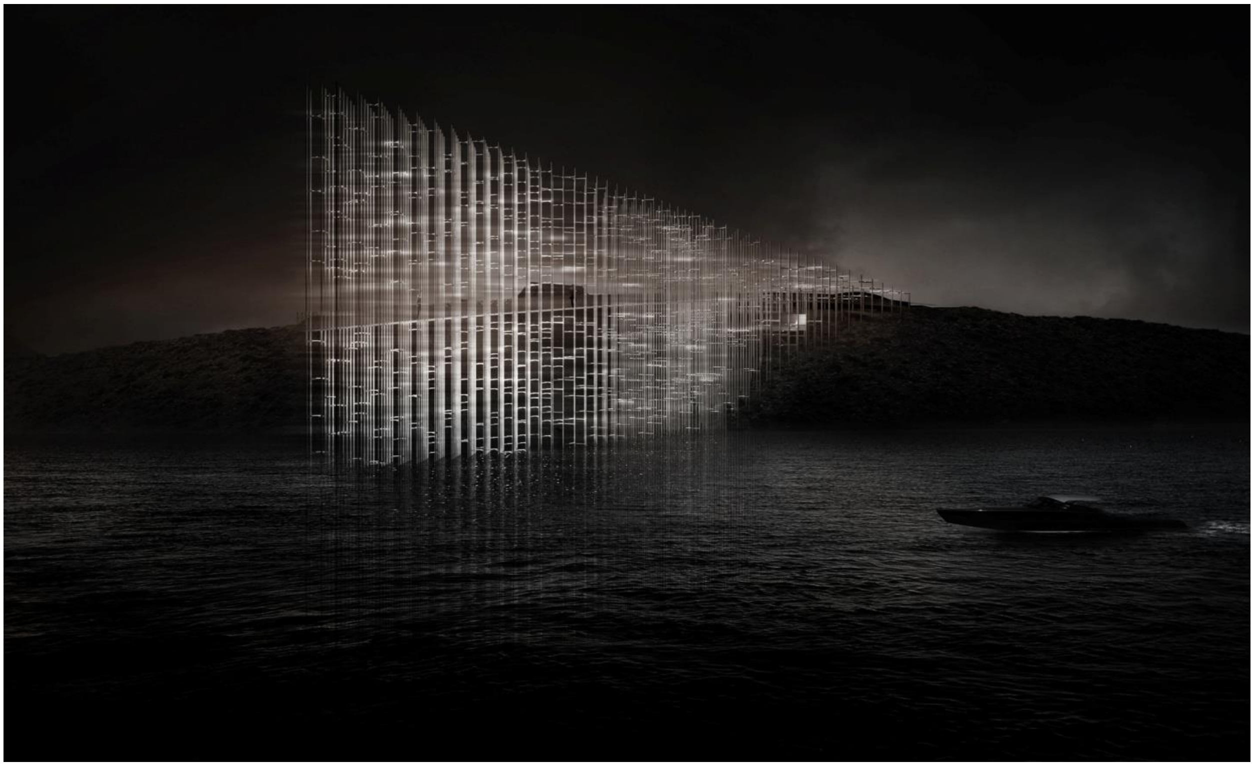
LABYRINTH

RIFT

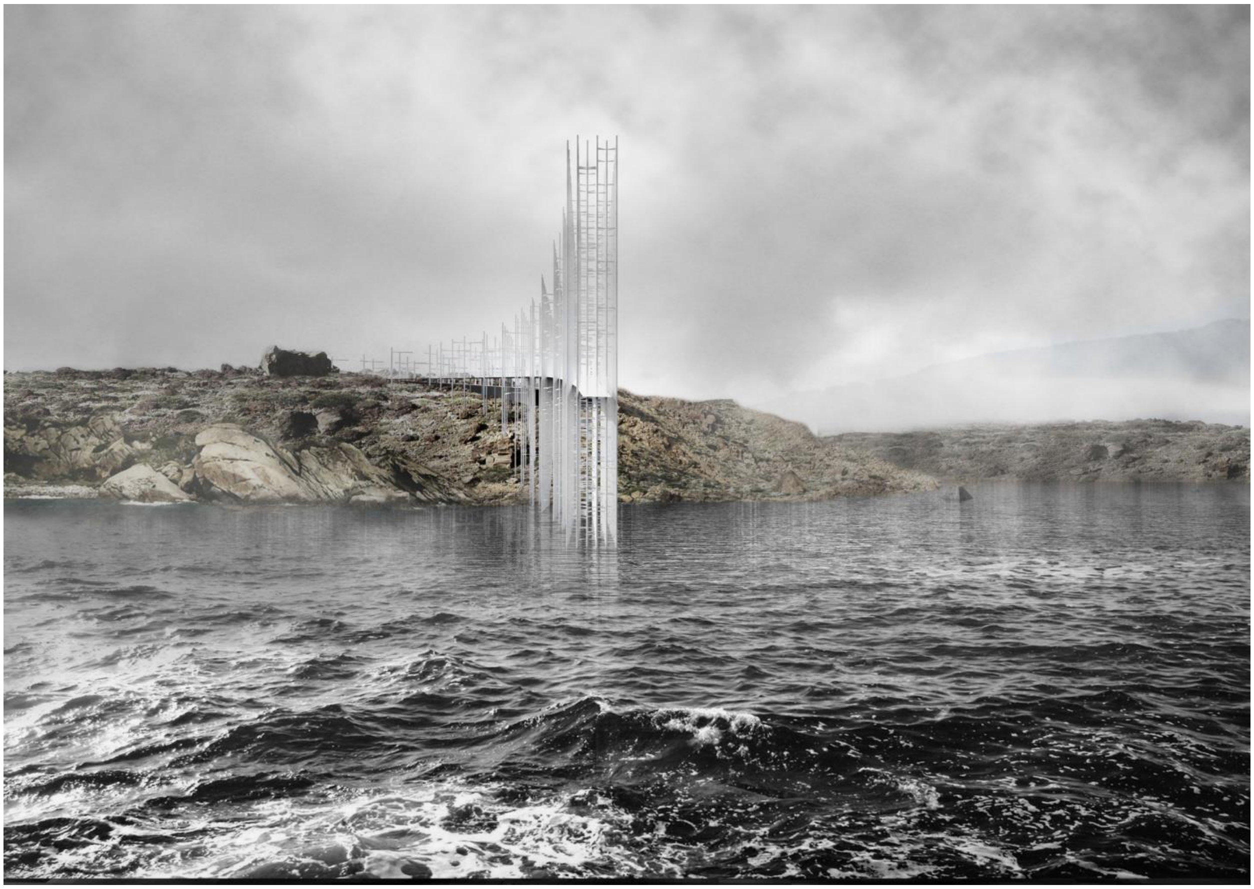
DESCENT

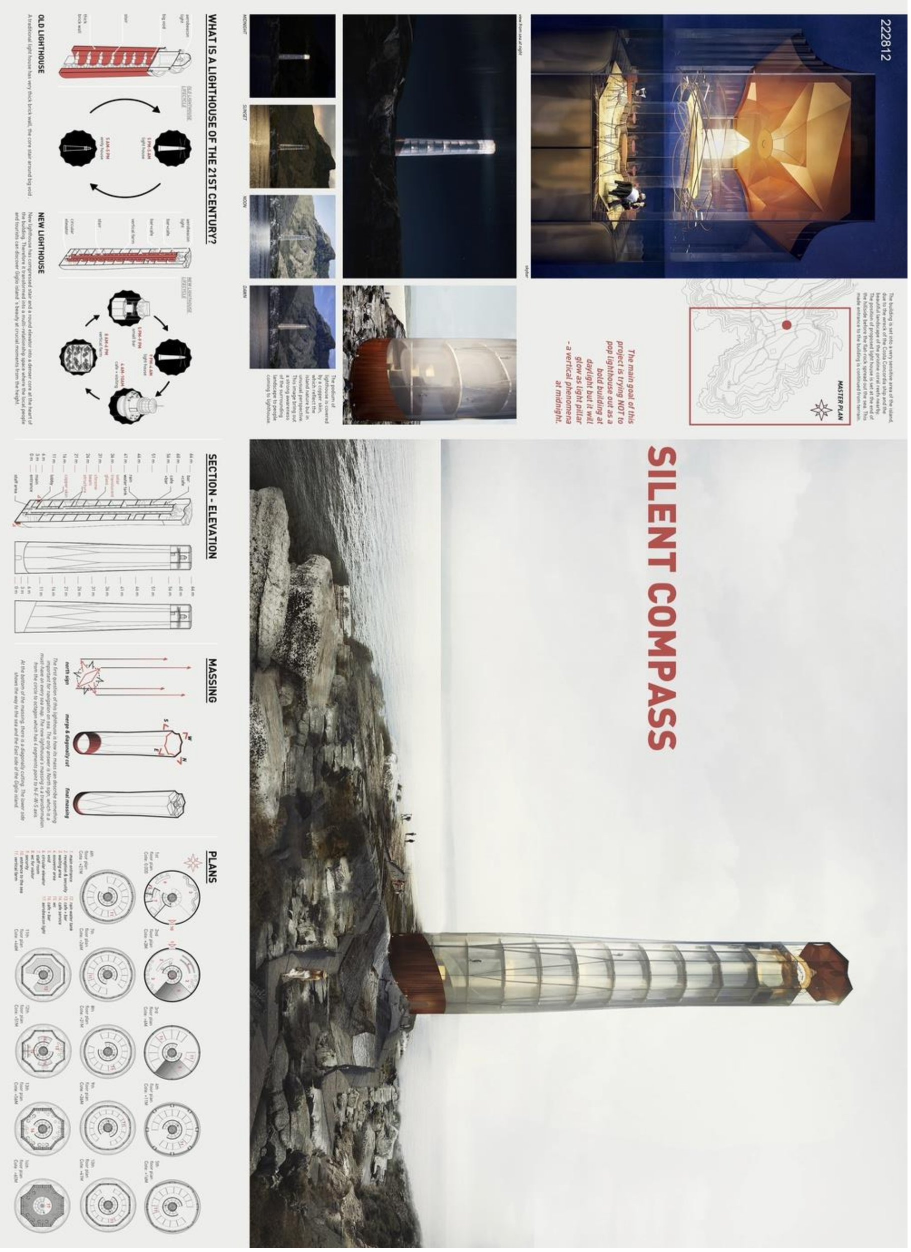
ASCENSION

CONCORDIA



FIRST PRIZE

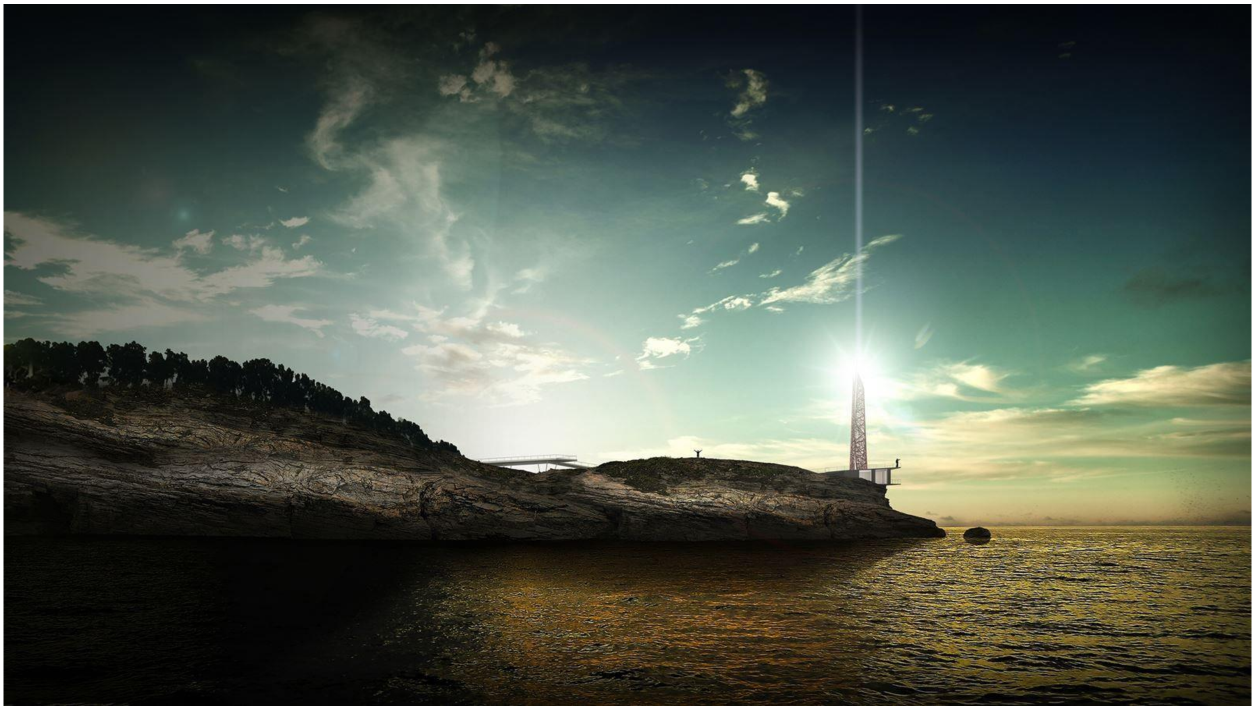


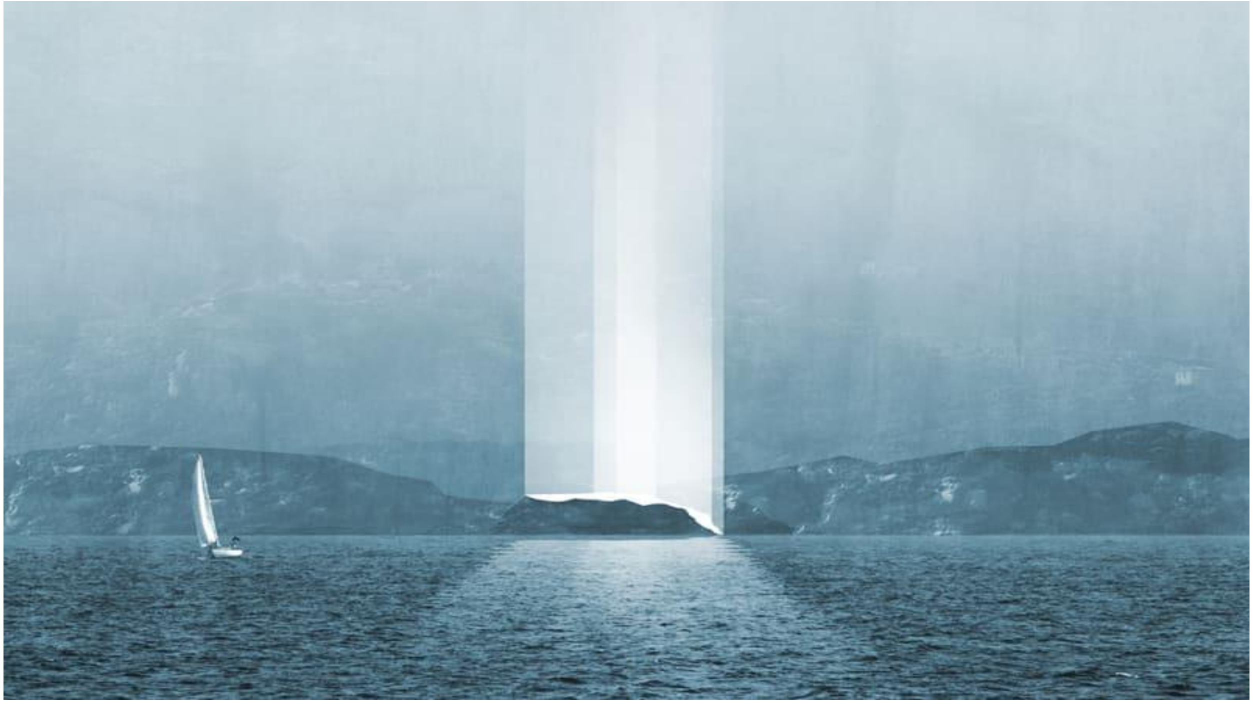


The building is set into a very sensitive area of the island, due to the wreck of the Costa Concordia ship and the beautiful landscape of the pristine coral reefs nearby. The position of proposed light house is set at the end of the hillside before the flat rock spread out the sea. This made entrance to the building is continued from terrain.

The main goal of this project is trying NOT to pop lighthouse out as a bold building at daylight but it will glow as light pillar - a vertical phenomena at midnight.

SECOND





COSTA CONCORDIA LIGHTHOUSE
GIGLIO ISLAND - ITALY
WITH VICTOR WICHROWSKI

REFERENCES

1. When the light goes out: The uncertain future of lighthouses, Stephanie Schorow Globe Correspondent,June 14, 2016, 10:00 p.m. https://www.bostonglobe.com/lifestyle/2016/06/14/lighthouses-remain-spotlight/GNrQyxfBCI7Ob7IIoMZKqM/story.html

The Lipstick as a Light House that lights lips. Japanese painting from 1978 by Takaesi Miraye

CHAPTER V

Technicals of Towers

Tall buildings are symbolic elements, carrying significant political, social, cultural and even religious meanings. Today cities compete to produce the tallest building in the world as a way of showcasing financial and economic power. Understanding the structures of these buildings, and how they support themselves as well as the loads imposed on them by the environment, is a fascinating way to see the real-life applications of physics. In the early 20th century, cities became bigger and denser. Urban populations were growing but land supply was limited. High-rise buildings became an essential solution to the problem. New technologies and building materials, such as industrial reinforced concrete, steel and elevators, made high-rise structures feasible and drove innovation.

The correct definition of 'tower' is a type of structure that is tall in proportion to the size of its base, often by a considerable margin. A tower is different from a tall building in that it is not built for habitation or for work, but serves other functions, primarily achieved by its height. However, towers may be intended for regular human access, for example as an observation platform.

Despite this, the term 'tower' is also sometimes applied to tall buildings, such as Trump Tower, Almas Tower, Princess Tower, Sea Sand Tower, and so on, and in the UK, high-rise residential buildings are often referred to as ‘tower blocks’.

Pure towers tend to be free-standing, self-supporting structures that do not use guy-wires (unlike masts). They can however be built attached to a building (such as a church tower or clock tower) or a wall (such as a watchtower).

The form of towers generally tapers upwards to ensure the load of the material at height can be supported by the structure below. They must also have sufficient stiffness to avoid buckling under applied loads such as heavy winds.

Historically, towers tended to be used for defensive or military purposes, and the term could be used to refer to an entire fortress, such as the Tower of London. The Romanesque and Gothic periods incorporated towers within the design of churches and cathedrals, sometimes with a spire or a flat roof. Towers were also commonly built onto prominent structures with clocks, such as town halls and other public buildings.

The development of structural steel as a framing device in the late-19th and early-20th centuries enabled towers to be built much taller, most notably, the Eiffel Tower in Paris.

Other types of tower include; cooling towers, water towers, communications towers, and so on.

Some of the most famous towers in the world include:

- Blackpool Tower.
- BT Tower.
- CN Tower.
- Eiffel Tower.
- Emley Moor transmitting station.
- Fernsehturm Berlin.
- Kobe Port Tower.
- Leaning Tower of Pisa.
- Space Needle.
- Watts Towers.

1.2 Loads and Forces on Buildings

What Is Load in Civil? There are different types of load than working on a structure, the design, location, and similar nature of which will vary. Design requirements are usually specified in terms of the maximum load that a structure must be able to withstand.The load is usually classified as either dead load or live load. The Types of Loads Acting on a Structure Are:

1. Dead Weight
2. Load applied
3. Wind load
4. Snow Weight
5. Earthquake load
6. Special load.

Dead loads, also known as permanent or static loads, are those that remain relatively constant over time and, for example, the weight of structural elements of a building, such as beams, walls, ceilings, and structural floors. The statics of a building deal with its structural stability. When an object is in equilibrium, the sum of all forces equals zero. Various forces from the environment, the weight of the building elements, furniture and equipment installations, users and other sources act on the building structure. Dead loads may include permanent non-structural partitions, fixed fixtures, and even built-in cupboards.

Live loads (applied or imposed loads) may vary over time. Typical live loads may include audience weight in an auditorium. Live load is a changing force generated by mobile objects inside the building, such as people within the building or stock in a warehouse. The force is gravitational. In short, the dead weight of a structure includes its full weight, usually measured in pounds per square foot before it goes into service Floors, walls, ceilings, columns, staircases, permanent appliances, and any fixed decoration create a static load that does not typically change over the life of the building. “loads account for non-dynamic forces having constant and permanent force on a structure.” Therefore, the calculation of dead load, the weight of its components, and pressures applied in a downward direction from the ground before taking additional load from living or use in a building must include the foundation system, the construction material employed, and concrete for any service. Equipment such as elevators, and ductwork, plumbing, fixed manufacturing equipment, etc.

Let us calculate the volume of the slab and multiply the density of the material from which it is made. For example, if you are working with a rectangular prismatic slab, you would multiply the area of the slab’s thickness and the resulting time density (for concrete, it is 2200 to 2400 kg per cubic meter).Once you have mass, it multiplies gravity to increase weight, which is the dead load. This is a concentrated load, so you should distribute it on the surface of the slab.As it may be noted that the phase thickness of the multiplication of the field is redundant, because, in the end, you would divide it at the same value, but I pointed it out because I think it is conceptually important.

Environmental Load: Environmental loads are forces acting on the building from its environment and may include wind, rain, earthquakes and temperature changes. The forces created can be either horizontal
or vertical, positive or negative.

1.2.1 Vertical Forces

Dead loads and live loads contribute to the vertical forces on the structure of buildings. Vertical loads are transferred from the floors to the columns and walls, and eventually to the soil or bedrock. At times, environmental loads also act vertically.

1.2.2 Horizontal Forces

Environmental loads contribute most of the horizontal forces acting on the structure of a building, with loads from wind being the most common. Architects refer to these horizontal forces as shear force. Adding cross bracing or shear walls can improve structural resistance to shear forces.

1.2.3 Internal Forces

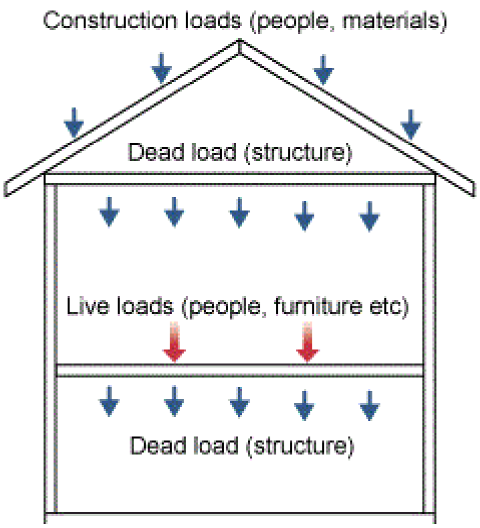
The internal strength of the entire structure must be equal to or larger than the total forces applied on the building in order to stay in equilibrium. The ability to withstand all forces depends on the structural component's dimensions and the solidity and elasticity of the material. Internal forces include compressive force, tensile force and torque.

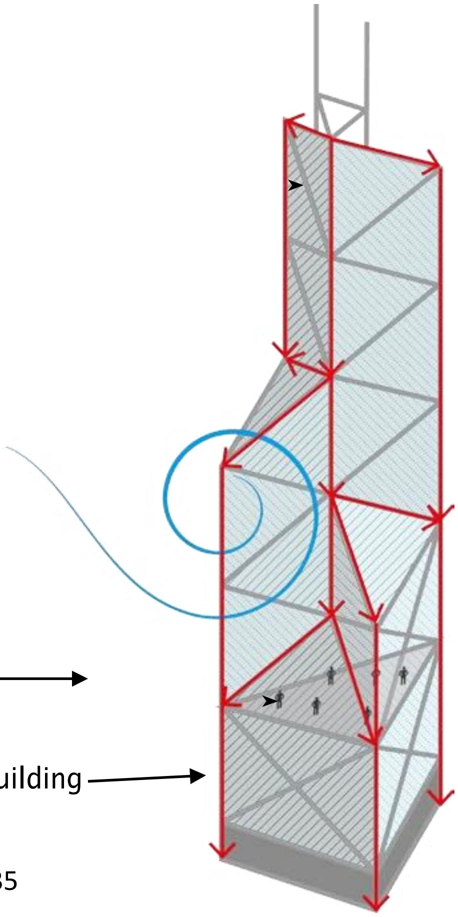
Compressive and Tensile Forces

According to Newton's Third Law, forces act in pairs. In structural terms, tensile force pulls a structural element apart while compressive force compresses it.

Torque

If opposing forces are applied at different points, a structural element may become twisted. This is called torque in the building industry.The loads are transferred to the ground via columns and pilings. Internal forces in a structural element Compressive force Tensile force Torque


Construction loads (people, materials)
Dead load (structure)
Live loads (people, furniture etc)
Dead load (structure)



Dead load e.g. Weight of the building

Environmental Loads e.g. Wind

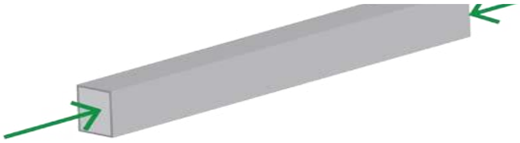
Live loads e.g. Weight of people at the building

The horizontal structural block is supported at two points. When a force is applied on the member between the two points, the upper surface of the member is in compression where the lower surface is in tension. On the other hand, vertical structural blocks are in compression mainly. The loads are then transferred to the earth.This shows the difference between the load-supporting behaviours of vertical members (e.g. columns and wall) and horizontal members (e.g. floor and ceiling). When the internal strength of a structural member cannot withstand the loads imposed on it, it will buckle or even break at the most stressed point.

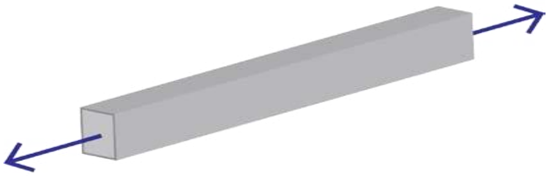
Possible perspectives: Cross bracing can be added at the joints of the horizontal and vertical block. Cross bracing is usually constructed of diagonal supports between structural members. It can resist both compression and tension forces, depending on the direction of the shear forces acting on the building.

Environmental Regulations: Before an edifice can pass the requirements, the structural design must also subsequently include other dynamic loads acting on it. These environmental loads can come from snow, soil movement, and seismic activity. Naturally, at different places codes are mild or severe, but certainly a factor of extreme snow, wind, and soil conditions.The different types classified as vertical loads, horizontal loads, and longitudinal loads. Vertical loads include dead loads, live loads, and impact loads.Horizontal loads include wind loads and earthquake loads. Longitudinal loads, i.e. tractive and braking forces, are considered in special cases of design of bridges, gantry girders, etc.

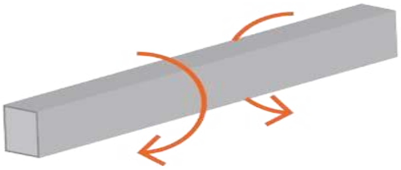
Compressive



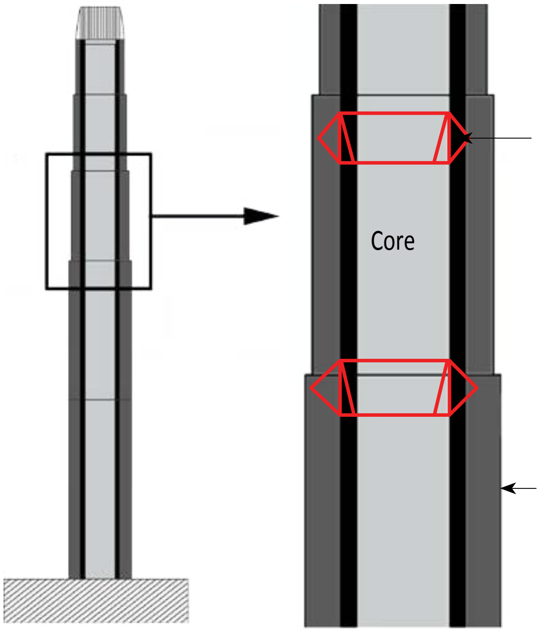
Tensile



Torque



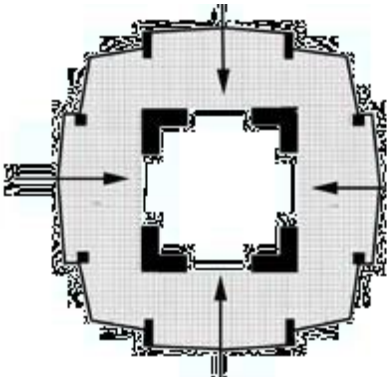
outrigger connecting core & column

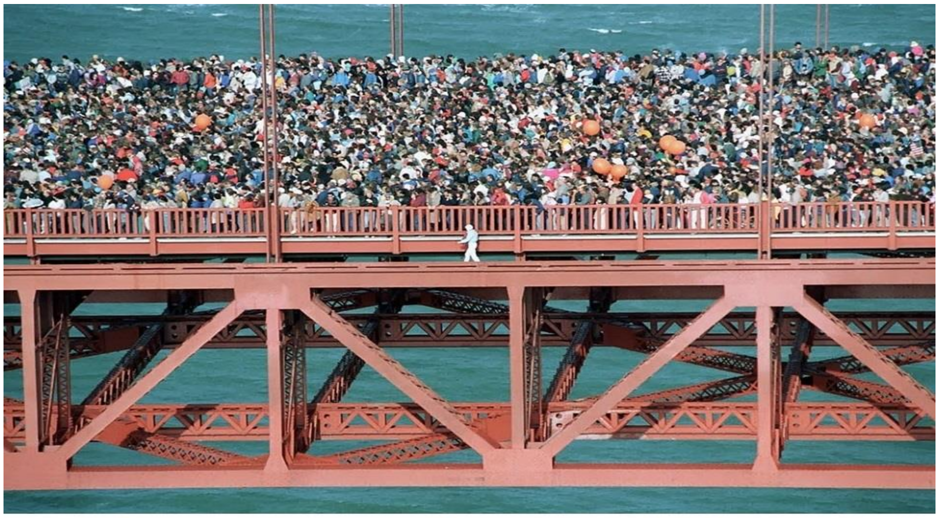


Perimeter colums carry less weight.

Weight is centralised to the core.

Outriggers help balancing lateral forces.



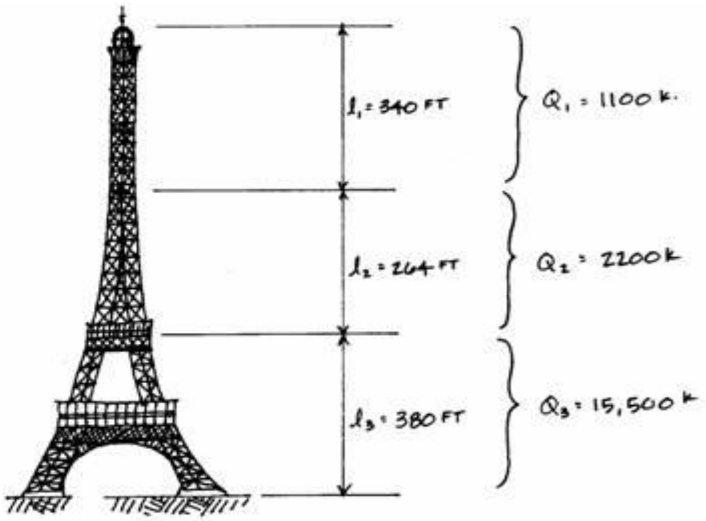


Golden Gate Bridge on its 50th Anniversary in May 1987: a classic example of live loads overload
AP Photo / Doug Atkins

LOADS: Taking the example of the Eiffel Tower. Three types of loads act on the Eiffel Tower:

- Dead load its own weight
- Live load the weight of people and machinery on the platforms
- Wind load

The weight of the Tower is known from documents to be 18,800 kips. This weight is not distributed uniformly along the height of the Tower; there is more material at the base than near the top. A detailed analysis would divide this weight among many parts of the Tower, but for our purposes, the weight will be divided among the three portions defined earlier. Estimates of these weights are shown below:

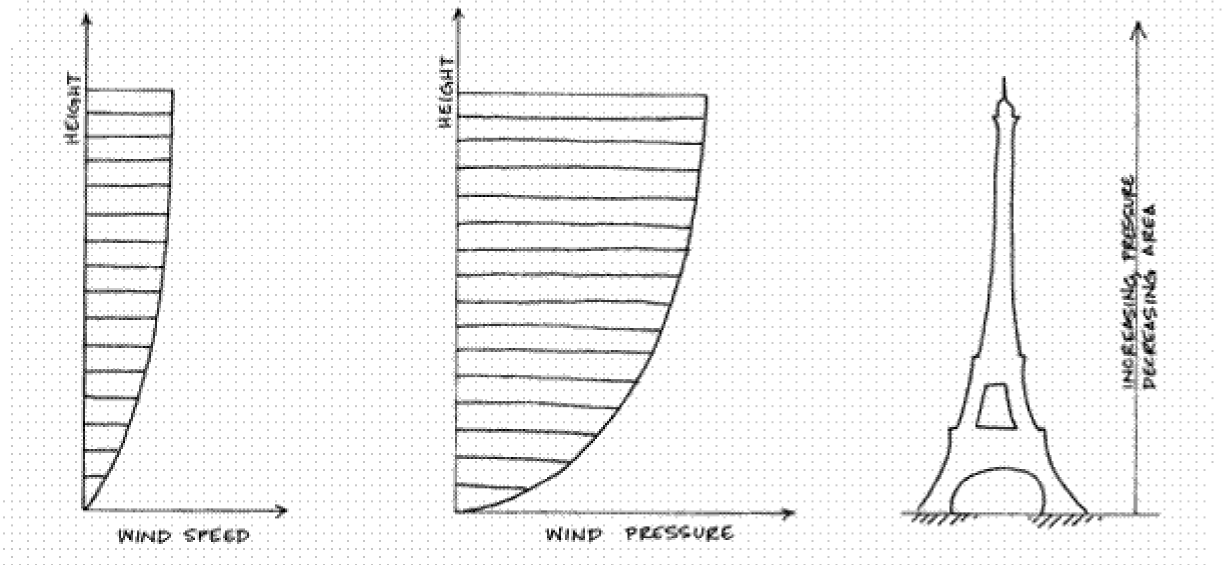


The live load of 50 pounds per square foot is calculated over the two lower platforms where it is most significant. The first platform is 240 square feet and the second platform is 110 square feet. The total live load is computed from the load on each of these platforms:

$$\begin{array}{lll} \text{1st Platform:} & \left(50\ \text{lb/ft}^2\right)\left(240\ \text{ft}\right)^2 = & 2880\ \text{k} \\ \underline{\text{2nd Platform:}} & \left(50\ \text{lb/ft}^2\right)\left(110\ \text{ft}\right)^2 = & \underline{\ 600\ \text{k}} \\ \text{Total Live Load:} & & 3480\ \text{k} \end{array}$$

This live load acts in combination with the dead load for a total vertical load of:

$$Q_t = 18,800\ \text{k} + 3480\ \text{k} = 22,280\ \text{k}$$

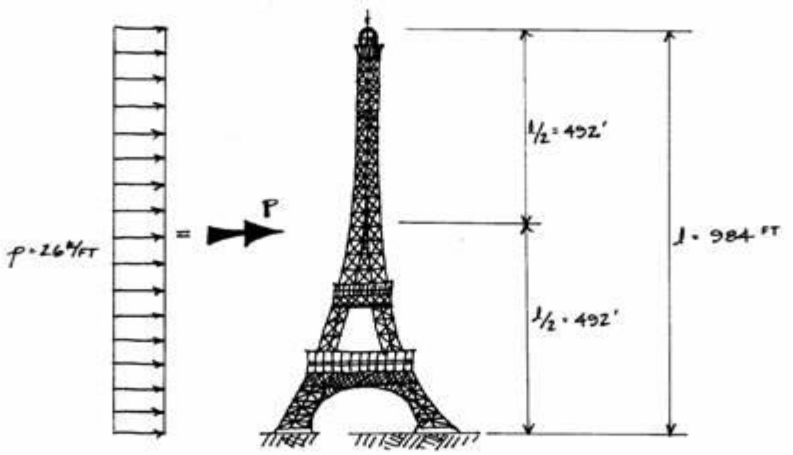


This load acts through the centroid of the Tower, which is located 257 feet above the ground.

The wind pressure on the Tower is stronger near the top than at the bottom, but the wind force is fairly uniform because the Tower is tapered. This analysis will use the assumption that the wind is a uniform load acting all along the Tower, but a conservatively high force is used to simulate high wind speeds. This value is taken as p = 2.6 k/ft. A more refined analysis would account for the variable force of the wind along with the diminishing area of the Tower. Realizing that the assumptions may produce imprecise results (but still good estimates) one can find the total force from the wind. Along the height of 984 feet, the total force is:

$$P = p \cdot l = (2.6\ \text{k/ft}) \cdot (984\ \text{ft})$$
$$= 2560\ \text{k}$$

The centroid of this force is halfway up the Tower so P, the idealized point wind load, acts at this point. This is illustrated in the following diagram:



Mechanics: Up to a certain height, a tower can be made with the supporting structure with parallel sides. However, above a certain height, the compressive load of the material is exceeded and the tower will fail. This can be avoided if the tower's support structure tapers up the building.

A second limit is that of buckling—the structure requires sufficient stiffness to avoid breaking under the loads it faces, especially those due to winds. Many very tall towers have their support structures at the periphery of the building, which greatly increases the overall stiffness.

A third limit is dynamic; a tower is subject to varying winds, vortex shedding, seismic disturbances etc. These are often dealt with through a combination of simple strength and stiffness, as well as in some cases tuned mass dampers to damp out movements. Varying or tapering the outer aspect of the tower with height avoids vibrations due to vortex shedding occurring along the entire building simultaneously.

Statute of Liberty in 1942 was a light house

Lighthouses mark dangerous coastlines, hazardous shoals, reefs, rocks and safe entries to harbors; they also assist in aerial navigation. Once widely used, the number of operational lighthouses has declined due to the expense of maintenance, and have become uneconomical since the advent of cheaper and often much more effective electronic navigational systems. Since elevating the fire would improve the visibility, placing the fire on a platform became a practice that led to the development of the lighthouse.[1] In antiquity, the lighthouse functioned more as an entrance marker to ports than as a warning signal for reefs and promontories, unlike many modern lighthouses. The most famous lighthouse structure from antiquity was the Pharos of Alexandria, Egypt, which collapsed following a series of earthquakes between 956 and 1323.

The intact Tower of Hercules at A Coruña, Spain gives insight into ancient lighthouse construction; other evidence about lighthouses exists in depictions on coins and mosaics, of which many represent the lighthouse at Ostia. Coins from Alexandria, Ostia, and Laodicea in Syria also exist.

Modern construction

The modern era of lighthouses began at the turn of the 18th century, as lighthouse construction boomed in lockstep with burgeoning levels of transatlantic commerce. Advances in structural engineering and new and efficient lighting equipment allowed for the creation of larger and more powerful lighthouses, including ones exposed to the sea. The function of lighthouses shifted toward the provision of a visible warning against shipping hazards, such as rocks or reefs.

The Eddystone Rocks were a major shipwreck hazard for mariners sailing through the English Channel. The first lighthouse built there was an octagonal wooden structure, anchored by 12 iron stanchions secured in the rock, and was built by Henry Winstanley from 1696 to 1698. His lighthouse was the first tower in the world to have been fully exposed to the open sea.

The civil engineer, John Smeaton, rebuilt the lighthouse from 1756–59;[4] his tower marked a major step forward in the design of lighthouses and remained in use until 1877. He modeled the shape of his lighthouse on that of an oak tree, using granite blocks. He rediscovered and used "hydraulic lime", a form of concrete that will set under water used by the Romans, and developed a technique of securing the granite blocks together using dovetail joints and marble dowels. The dovetailing feature served to improve the structural stability, although

Smeaton also had to taper the thickness of the tower towards the top, for which he curved the tower inwards on a gentle gradient. This profile had the added advantage of allowing some of the energy of the waves to dissipate on impact with the walls. His lighthouse was the prototype for the modern lighthouse and influenced all subsequent engineers.

One such influence was Robert Stevenson, himself a seminal figure in the development of lighthouse design and construction.His greatest achievement was the construction of the Bell Rock Lighthouse in 1810, one of the most impressive feats of engineering of the age. This structure was based upon Smeaton's design, but with several improved features, such as the incorporation of rotating lights, alternating between red and white. Stevenson worked for the Northern Lighthouse Board for nearly fifty years during which time he designed and oversaw the construction and later improvement of numerous lighthouses. He innovated in the choice of light sources, mountings, reflector design, the use of Fresnel lenses, and in rotation and shuttering systems providing lighthouses with individual signatures allowing them to be identified by seafarers. He also invented the movable jib and the balance-crane as a necessary part for lighthouse construction.

Alexander Mitchell designed the first screw-pile lighthouse – his lighthouse was built on piles that were screwed into the sandy or muddy seabed. Construction of his design began in 1838 at the mouth of the Thames and was known as the Maplin Sands lighthouse, and first lit in 1841. Although its construction began later, the Wyre Light in Fleetwood, Lancashire, was the first to be lit (in 1840).

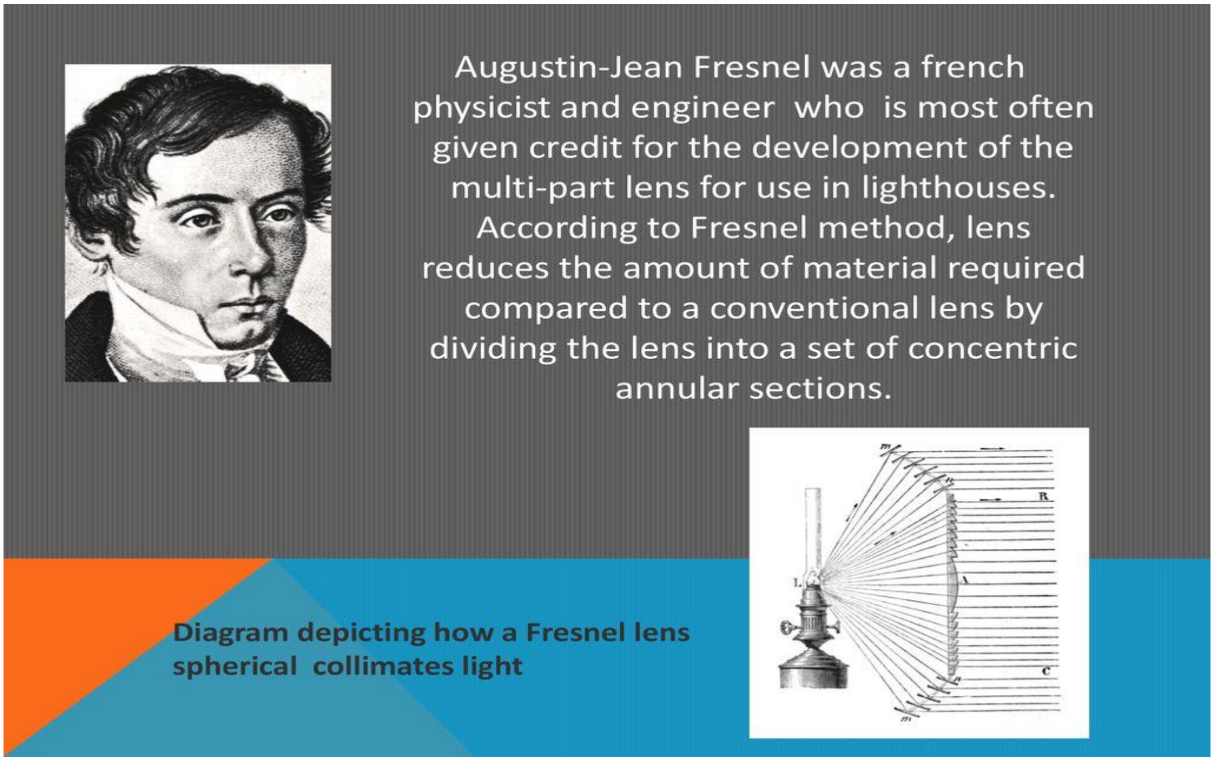
Lighting improvements

The source of illumination had generally been wood pyres or burning coal. The Argand lamp, invented in 1782 by the Swiss scientist, Aimé Argand, revolutionized lighthouse illumination with its steady smokeless flame. Early models used ground glass which was sometimes tinted around the wick. Later models used a mantle of thorium dioxide suspended over the flame, creating a bright, steady lightThe Argand lamp used whale oil, colza, olive oil or other vegetable oil as fuel which was supplied by a gravity feed from a reservoir mounted above the burner. The lamp was first produced by Matthew Boulton, in partnership with Argand, in 1784 and became the standard for lighthouses for over a century.

South Foreland Lighthouse was the first tower to successfully use an electric light in 1875. The lighthouse's carbon arc lamps were powered by a steam-driven magneto. John Richardson Wigham was the first to develop a system for gas illumination of lighthouses. His improved gas 'crocus' burner at the Baily Lighthouse near Dublin was 13 times more powerful than the most brilliant light then known.

The vaporized oil burner was invented in 1901 by Arthur Kitson, and improved by David Hood at Trinity House. The fuel was vaporized at high pressure and burned to heat the mantle, giving an output of over six times the luminosity of traditional oil lights. The use of gas as illuminant became widely available with the invention of the Dalén light by Swedish engineer, Gustaf Dalén. He used Agamassan (Aga), a substrate, to absorb the gas allowing safe storage and hence commercial exploitation. Dalén also invented the 'sun valve', which automatically regulated the light and turned it off during the daytime. The technology was the predominant form of light source in lighthouses from the 1900s through the 1960s, when electric lighting had become dominant

Optical systems

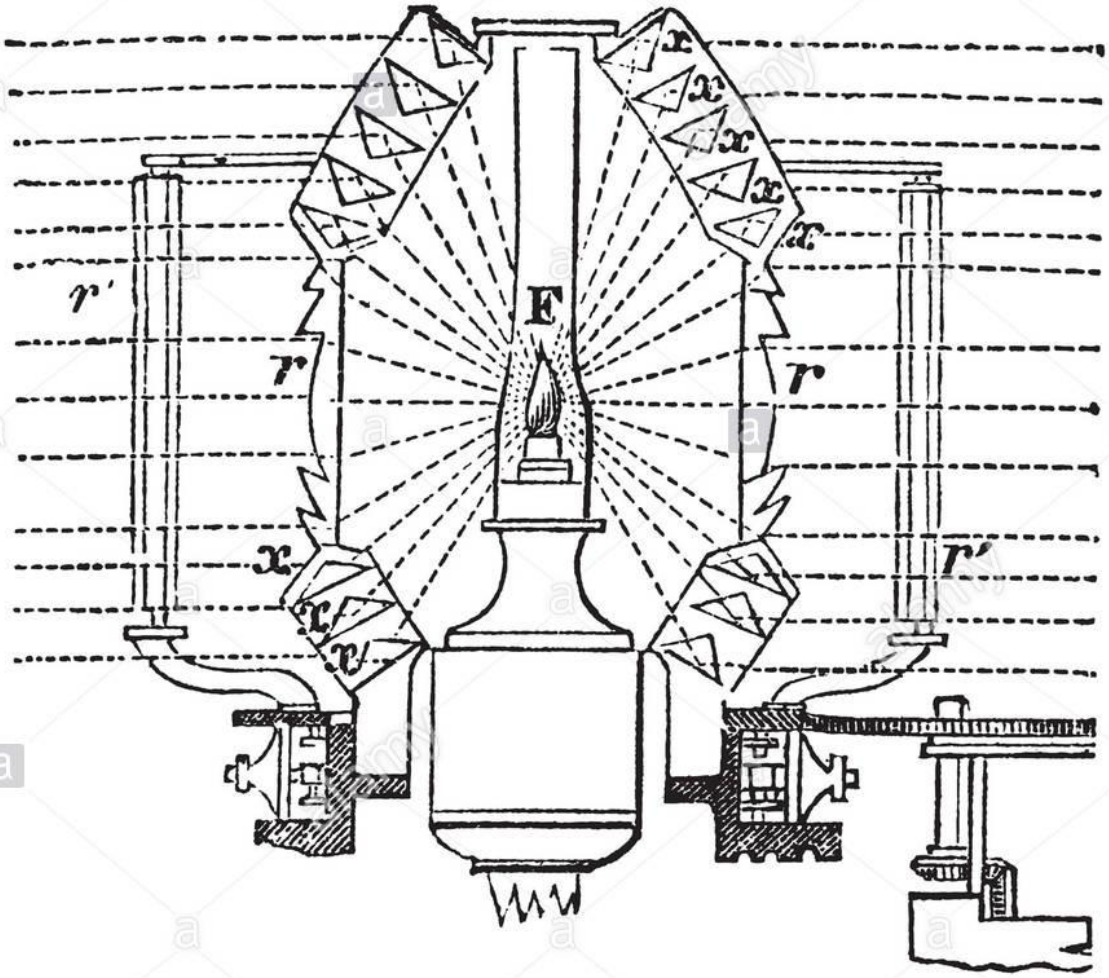


Augustin-Jean Fresnel was a french physicist and engineer who is most often given credit for the development of the multi-part lens for use in lighthouses. According to Fresnel method, lens reduces the amount of material required compared to a conventional lens by dividing the lens into a set of concentric annular sections.

Diagram depicting how a Fresnel lens spherical collimates light

With the development of the steady illumination of the Argand lamp, the application of optical lenses to increase and focus the light intensity became a practical possibility. William Hutchinson developed the first practical optical system in 1763, known as a catoptric system. This rudimentary system effectively collimated the emitted light into a concentrated beam, thereby greatly increasing the light's visibility. The ability to focus the light led to the first revolving lighthouse beams, where the light would appear to the mariners as a series of intermittent flashes. It also became possible to transmit complex signals using the light flashes.

French physicist and engineer Augustin-Jean Fresnel developed the multi-part Fresnel lens for use in lighthouses. His design allowed for the construction of lenses of large aperture and short focal length, without the mass and volume of material that would be required by a lens of conventional design. A Fresnel lens can be made much thinner than a comparable conventional lens, in some cases taking the form of a flat sheet. A Fresnel lens can also capture more oblique light from a light source, thus allowing the light from a lighthouse equipped with one to be visible over greater distances.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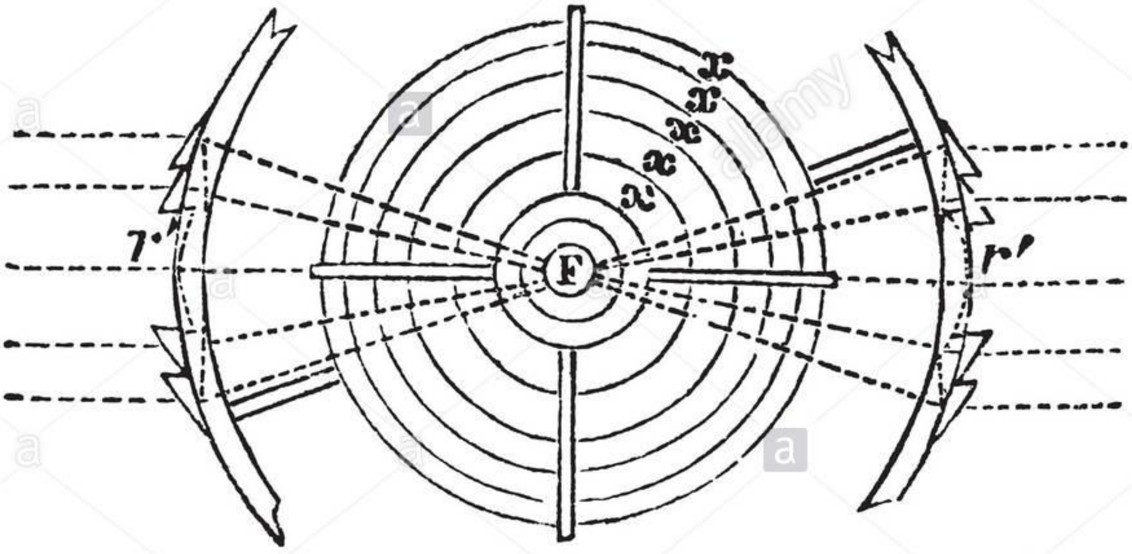
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The first Fresnel lens was used in 1823 in the Cordouan lighthouse at the mouth of the Gironde estuary; its light could be seen from more than 20 miles (32 km) out. Fresnel's invention increased the luminosity of the lighthouse lamp by a factor of four and his system is still in common use.

Recent

The advent of electrification, and automatic lamp changers began to make lighthouse keepers obsolete. For many years, lighthouses still had keepers, partly because lighthouse keepers could serve as a rescue service if necessary. Improvements in maritime navigation and safety such as the Global Positioning System (GPS) have led to the phasing out of non-automated lighthouses across the world. In Canada, this trend has been stopped and there are still 50 staffed light stations, with 27 on the west coast alone.

Remaining modern lighthouses are usually illuminated by a single stationary flashing light powered by solar-charged batteries mounted on a steel skeleton tower. Where the power requirement is too great for solar power, *cycle charging* by diesel generator is used: to save fuel and to increase periods between maintenance the light is battery powered, with the generator only coming into use when the battery has to be charged.

Famous lighthouse builders

John Smeaton is noteworthy for having designed the third and most famous Eddystone Lighthouse, but some builders are well known for their work in building multiple lighthouses. The Stevenson family (Robert, Alan, David, Thomas, David Alan, and Charles) made lighthouse building a three-generation profession in Scotland. Irishman Alexander Mitchell invented and built a number of screwpile lighthouses despite his blindness. Englishman James Douglass was knighted for his work on lighthouses.

United States Army Corps of Engineers Lieutenant George Meade built numerous lighthouses along the Atlantic and Gulf coasts before gaining wider fame as the winning general at the Battle of Gettysburg. Colonel Orlando M. Poe, engineer to General William Tecumseh Sherman in the Siege of Atlanta, designed and built some of the most exotic lighthouses in the most difficult locations on the U.S. Great Lakes.

French merchant navy officer Marius Michel Pasha built almost a hundred lighthouses along the coasts of the Ottoman Empire in a period of twenty years after the Crimean War (1853–1856).

Power

In a lighthouse, the source of light is called the "lamp" (whether electric or fuelled by oil) and the concentration of the light is by the "lens" or "optic". Originally lit by open fires and later candles, the Argand hollow wick lamp and parabolic reflector were introduced in the late 18th century.

Whale oil was also used with wicks as the source of light. Kerosene became popular in the 1870s and electricity and carbide (acetylene gas) began replacing kerosene around the turn of the 20th century. Carbide was promoted by the Dalén light which automatically lit the lamp at nightfall and extinguished it at dawn.

During the Cold-War, many remote Soviet lighthouses were powered by radioisotope thermoelectric generators (RTGs). These had the advantage of providing power day or night and did not need refuelling or maintenance. However, after the breakdown of the Soviet Union, there are no official records of the locations or condition of all of these lighthouses.[23] As time passes, their condition is degrading; many have fallen victim to vandalism and scrap metal thieves, who may not be aware of the dangerous radioactive contents.

Lens

Cape Meares Lighthouse; first-order Fresnel lens

Before modern strobe lights, lenses were used to concentrate the light from a continuous source. Vertical light rays of the lamp are redirected into a horizontal plane, and horizontally the light is focused into one or a few directions at a time, with the light beam swept around. As a result, in addition to seeing the side of the light beam, the light is directly visible from greater distances, and with an identifying light characteristic.

This concentration of light is accomplished with a rotating lens assembly. In early lighthouses, the light source was a kerosene lamp or, earlier, an animal or vegetable oil Argand lamp, and the lenses rotated by a weight driven clockwork assembly wound by lighthouse keepers, sometimes as often as every two hours. The lens assembly sometimes floated in liquid mercury to reduce friction. In more modern lighthouses, electric lights and motor drives were used, generally powered by diesel electric generators. These also supplied electricity for the lighthouse keepers.

Efficiently concentrating the light from a large omnidirectional light source requires a very large diameter lens. This would require a very thick and heavy lens if a conventional lens were used. The Fresnel lens focused 85% of a lamp's light versus the 20% focused with the parabolic reflectors of the time. Its design enabled construction of lenses of large size and short focal length without the weight and volume of material in conventional lens designs.

Fresnel lighthouse lenses are ranked by *order*, a measure of refracting power, with a first order lens being the largest, most powerful and expensive; and a sixth order lens being the smallest. The order is based on the focal length of the lens. A first order lens has the longest focal length, with the sixth being the shortest. Coastal lighthouses generally use first, second, or third order lenses, while harbor lights and beacons use fourth, fifth, or sixth order lenses.

Some lighthouses, such as those at Cape Race, Newfoundland, and Makapuu Point, Hawaii, used a more powerful hyperradiant Fresnel lens manufactured by the firm of Chance Brothers.

In recent times, many Fresnel lenses have been replaced by rotating aerobeacons which require less maintenance. In modern automated lighthouses, this system of rotating lenses is often replaced by a high intensity light that emits brief omnidirectional flashes (concentrating the light in time rather than direction). These lights are similar to obstruction lights used to warn aircraft of tall structures. Recent innovations are "Vega Lights", and initial experiments with light-emitting diode (LED) panels.

Laser light

Experimental installations of laser lights, either at high power to provide a "line of light" in the sky or, utilising low power, aimed towards mariners have identified problems of increased complexity in installation and maintenance, and high power requirements.Constructed in 1971, it commemorates the bicentennial of Captain Cook's first voyage, and specifically the voyage along the east coast of Australia in 1770.[6] It was first exhibited on 18 April 1971.The original light source was an experimental laser-based light, and the lighthouse may very well be the first in the world to experiment with this light source. However, the experiment failed, and the light source was replaced in 1975 by a regular electric lamp.

Current display

The light characteristic shown is two white flashes every ten seconds (Fl.(2)W. 10s), visible at 170°-330° for 11 nautical miles (20 km; 13 mi). The light source is an electric lamp, fed by a battery float charged from the mains electricity.

Point Danger lighthouse, Queensland, 1971, used a laser light source but the equipment was replaced by a conventional electric light in 1975

The lighthouse is constructed of four concrete columns, marked with the four cardinal directions, and a bronze sculpture hung between the columns. Also, near-by is a one-story building housing the Marine Rescue NSW Point Danger station.

Light characteristics

In any of these designs an observer, rather than seeing a continuous weak light, sees a brighter light during short time intervals. These instants of bright light are arranged to create a light characteristic or pattern specific to a lighthouse. For example, the Scheveningen Lighthouse flashes are alternately 2.5 and 7.5 seconds. Some lights have sectors of a particular color (usually formed by colored panes in the lantern) to distinguish safe water areas from dangerous shoals. Modern lighthouses often have unique reflectors or Racon transponders so the radar signature of the light is also unique.

Jeddha lights Jeddha, Saudi Arabia

Jeddah Light is an active lighthouse in Jeddah, Saudi Arabia. With a height of about 133 m (436 ft) it "has a credible claim to be the world's tallest light tower". It is located at the end of the outer pier on the north side of the entrance to Jeddah Seaport.

Name-Jeddah Port Control Tower
Alternative name-Jeddah Islamic Port-Control Tower
EBN-223127

Location

City-Jeddah

State-Makkah [مكة]

Country- Saudi Arabia

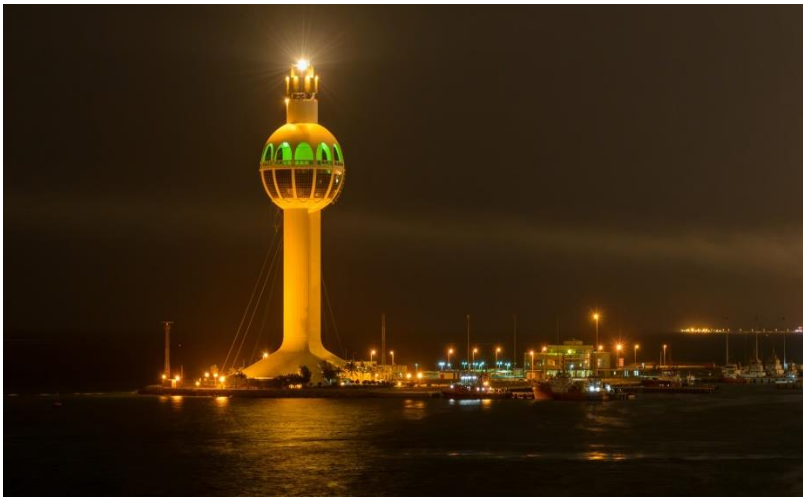
Technical Data

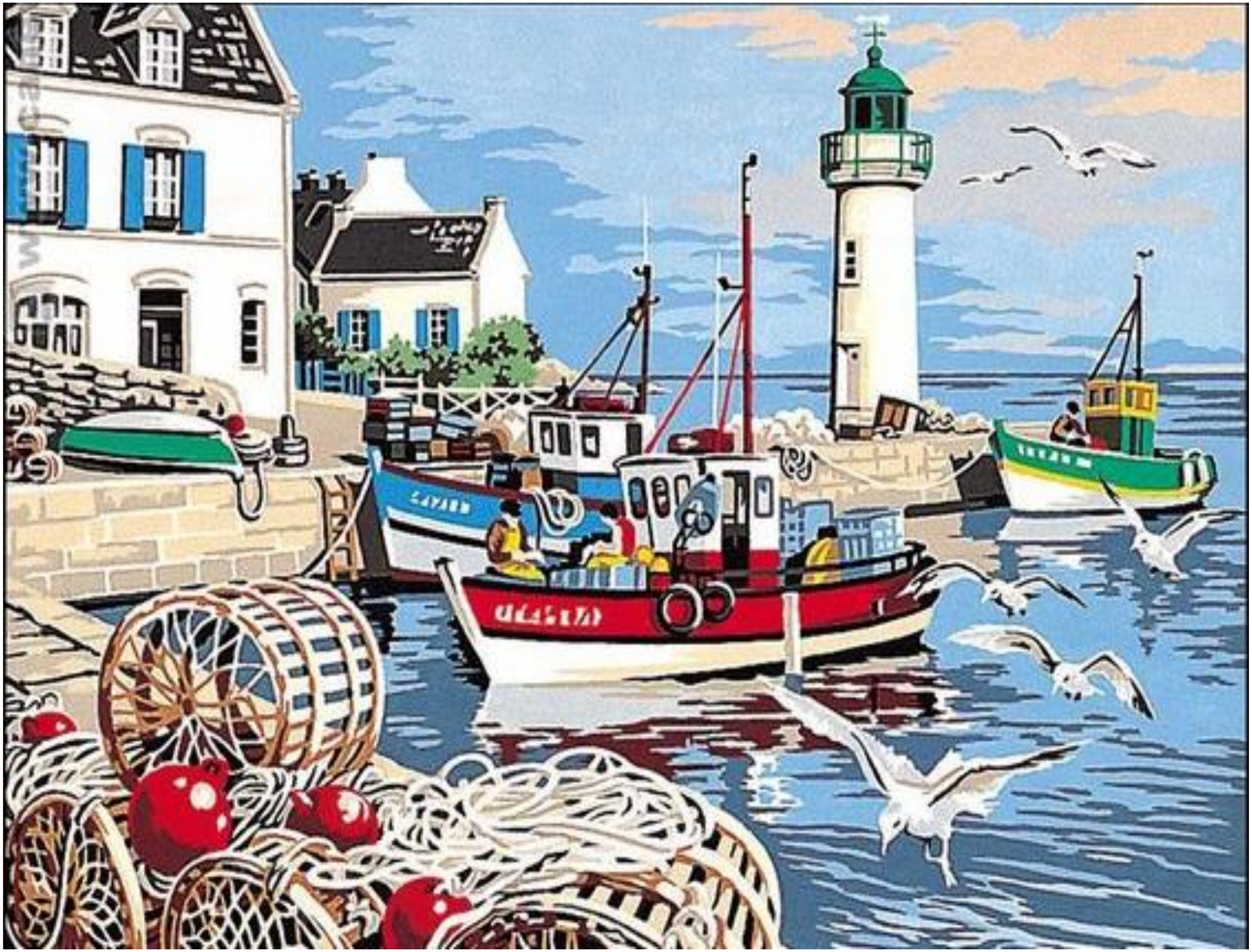
Height (architectural)-131.40 m

Construction start-1987

Construction end-1990

Elevators-9





CHAPTER VI

The Collossus of Rhodes as a Light House

Seven Wonders of the Ancient World

- Great Pyramid of Giza
- Hanging Gardens of Babylon
- Statue of Zeus at Olympia
- Temple of Artemis
- Mausoleum of Maussollos
- Colossus of Rhodes
- Lighthouse of Alexandria

Introduction: The Colossus of Rhodes was a statue of the Greek sun-god Helios, erected in the city of Rhodes, on the Greek island of the same name, by Chares of Lindos in 280 BC. One of the Seven Wonders of the Ancient World, it was constructed to celebrate its successful defense against Demetrius Poliorcetes, who had besieged it for a year with a large army and navy. According to most contemporary descriptions, the Colossus stood approximately 70 cubits, or 33 metres (108 feet) high—the approximate height of the modern Statue of Liberty from feet to crown—making it the tallest statue of the ancient world. It collapsed during the earthquake of 226 BC, although parts of it were preserved. In accordance with a certain oracle, the Rhodians did not build it again. John Malalas wrote that Hadrian in his reign reerected the Colossus but he was wrong. According to Suda the Rhodians were called Colossaeans (Κολοσσαεῖς), because they erected on the island the statue.

Colossus of Rhodes

The patron god of the island of Rhodes) constructed between 292 and 280 BCE. Stood overlooking the harbor of Rhodes and, despite fanciful depictions to the contrary, stood with its legs together on a base (much like the Statue of Liberty in the harbor off New York City in the United States of America, which is modeled on the Colossus) and did not straddle the harbour. The statue was commissioned after the defeat of the invading army of Demetrius in 304 BCE. Demetrius left behind much of his siege equipment and weaponry, and this was sold by the Rhodians for 300 talents (approximately 360 million US dollars) which money they used to build the Colossus. The statue stood for only 56 years before it was destroyed by an earthquake in 226 BCE. It lay in impressive ruin for over 800 years, according to Strabo, and was still a tourist attraction. Pliny the Elder claims that the fingers of the Colossus were larger than most statues of his day. According to the historian Theophanes, the bronze ruins were eventually sold to “a Jewish merchant of Edessa” around 654 CE who carried them away on 900 camels to be melted down.

Ancient Rhodes by Frantisek Kupka

Location

Rhodes is the largest Greek island in the Dodecanese archipelago. It is only 19 km away from the Turkish coast. The port of the capital, also named Rhodes is the place where the statue was located but no one knows the exact location. The archaeological excavations have not yet given anything, which is hardly surprising since the site had to be much smaller than, for example, the site of the temple of Artemis. Moreover once collapsed the statue remained in the state for a long time, then the site was cleared. It is probably that the urbanization of Rhodes and its harbor was due to the hypothetical vestiges, which makes it impossible to know precisely where it was today.

What we can say is that the city of Rhodes was protected by a rampart of 15Km long and a wide ditch, forcing the assailants to use a tower to enter the city, and that the city possessed a large temple already dedicated to Helios. It must be said that this God was the protector of Rhodes. Some people think that the statue was located near this temple, but the representations that have come down to us indicate that it was rather at the entrance to the port.

Several representations show a statue spanning the entrance to the port. Such a configuration could not be envisaged because it was more than 30m high, and if the proportions were correct - and there is no reason to believe the contrary - the small width allowed by the spacing of the legs would have caused a unacceptable shrinkage of port entrance. Moreover, she would simply not have stood up, it is physically impossible. And finally, if it had been so done, it would have collapsed in the entrance of the harbor and not on the mainland, as it is attested to be. This hypothesis is therefore to be analyzed.

Reasons of the construction

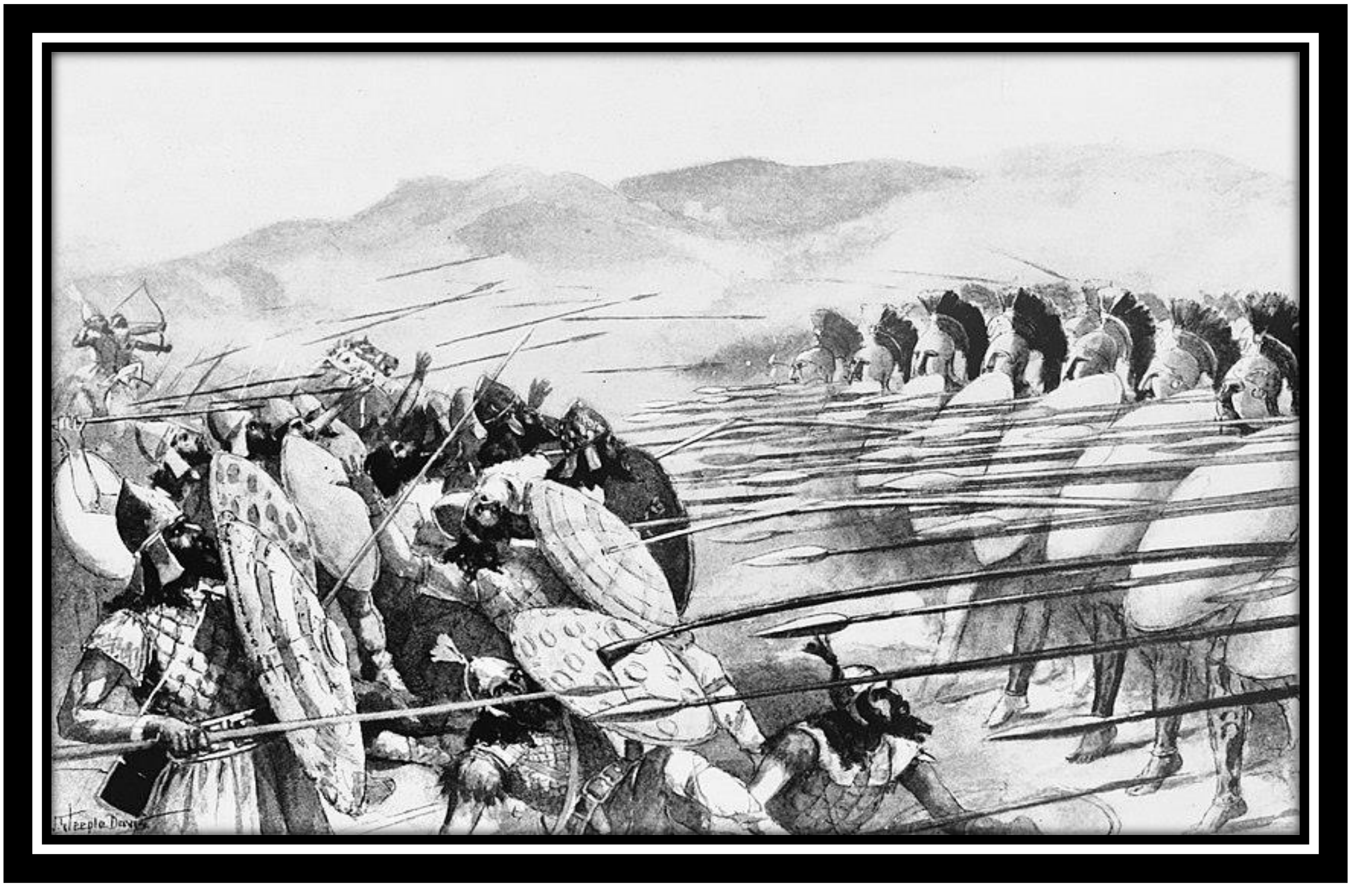
The reason why the Rhodanians built this tower is simple, following a victory they won in 304. That year the island survived a terrible siege caused by Demetrios Poliorcete, Alexander the Great, who had received the order of Antigonus to become master of the Mediterranean and to assert his dominion over the Greek islands. The siege was held for a year, between 305 and 304 BC, and was held by Rhodes, engendering the satisfaction of the inhabitants who saw a divine will, especially since it was the third seat in only 30 years. To thank the protective God Helios, they decided to build a gigantic statue, it is as simple as that.

It should be noted that during the Antiquity the island of Rhodes was famous for its statues, and according to the Roman author Pliny, the capital was proud to possess 3000, often in stone, sometimes in bronze, but if the quantity of statues of the island made it a characteristic, it did not yet possess gigantic statues, a titanic statue as they are called today. The city of Olympus had one, it was made by Phidias, Greek sculptor who conceived the Statue of Zeus, a chryséléphantine statue of 13m high, another of the 7 wonders of the world. He had previously made the statue of Athena, another chryshephantine statue, but this one was a little smaller, only 9m. Previously, other nations have produced gigantic statues, Rhodes had to have his own, and the opportunity had come.

Dimensions: Construction began in 292 BC. Ancient accounts, which differ to some degree, describe the structure as being built with iron tie bars to which brass plates were fixed to form the skin. The base pedestal was said to be at least 18 metres (59 feet) in diameter, and either circular or octagonal. The feet were carved in stone and covered with thin bronze plates riveted together. Eight forged iron bars set in a radiating horizontal position formed the ankles and turned up to follow the lines of the legs while becoming progressively smaller. Individually cast curved bronze plates 60 inches (1,500 mm) square with turned-in edges were joined together by rivets through holes formed during casting to form a series of rings. The lower plates were one inch (25 mm) in thickness to the knee and ¾-inch (20 mm) thick from knee to abdomen, while the upper plates were ¼–½-inch (6.5–12.5 mm) thick except where additional strength was required at joints such as the shoulder, neck, etc.

The interior of the structure, which stood on a 15-metre-high (49-foot) white marble pedestal near the Mandraki harbour entrance, was then filled with stone blocks as construction progressed. Other sources place the Colossus on a breakwater in the harbour. According to most contemporary descriptions, the statue itself was about 70 cubits, or 32 metres (105 feet) tall. Much of the iron and bronze was reforged from the various weapons Demetrius's army left behind, and the abandoned second siege tower may have been used for scaffolding around the lower levels during construction. Upper portions were built with the use of a large earthen ramp. During the building, workers would pile mounds of earth on the sides of the colossus. Upon completion all of the earth was removed and the colossus was left to stand alone. After twelve years, in 280 BC, the statue was completed. Preserved in Greek anthologies of poetry is what is believed to be the genuine dedication text for the Colossus.

> *To you, O Sun, the people of Dorian Rhodes set up this bronze statue reaching to Olympus, when they had pacified the waves of war and crowned their city with the spoils taken from the enemy. Not only over the seas but also on land did they kindle the lovely torch of freedom and independence. For to the descendants of Herakles belongs dominion over sea and land.*



Funding

Funding has been rather original, it is the first time that has happened in the history of humanity, at least for the major works of which we know the financing: Money was found by selling the military equipment abandoned on the ground by Demetrios Poliorcete who, with 40,000 soldiers, had led the attack on the capital of the island. It should be known that during the 4th century BC Rhodes experienced a major economic boom. She had allied with King Ptolemy Soter I of Egypt. In 305 BC the Antogonids of Macedonia, who were rivals to the Ptolemies, attacked the island but without success. It was from this battle that the military equipment that was used to finance the colossus was recovered.

There is no doubt that other funding had to be found, but it is not known in what proportion it was or who contributed it. Often in such a case it is the people who abound to build the monument that will ensure the aura of the city.

Modern engineers have put forward a plausible hypothesis for the statue's construction, based on the technology of the time (which was not based on the modern principles of earthquake engineering), and the accounts of Philo and Pliny, who saw and described the ruins.

The construction of the statute took 12 years and begun in 292 BC. It holds the sad record of the world's shortest wonder: 60 years later it was already demolished, where the pyramid of Cheops is still standing despite its 4,500 years.

Description of the colossus

With such a short life it is difficult to know exactly what this statue looked like. However, its popularity was such that it was described and reproduced several times, and by crossing this information it came to be known that it was an almost naked man wearing a crown of solar rays on his head and brandishing a torch. It was 32m high and was made of bronze, except the pedestal and feet, on which it was mounted, which were of marble, a material renowned for its solidity.It is said that the face of the colossus of Rhodes was that of Alexander the Great, but it is impossible to confirm or disprove it. However, this is unlikely.

The sculptor, Charès de Lindos

The sculptor of the Colossus of Rhodes is well known, it is Chares of Lindos. Lindos is simply one of the three major cities of Rhodes.Chares was a follower of a realistic style, as was Phidias, the sculptor of the Statue of Zeus, another of the wonders of the world. This style is much more complex to implement because it requires a great mastery in the reproduction of a character. This style allows to magnify the realism of the statue and to translate the force and the movement.

Modality: Ancient accounts, which differ to some degree, describe the structure as being built around several stone columns (or towers of blocks) forming the interior of the structure, which stood on a 50-foot-high, white marble pedestal near the Mandraki harbor entrance. Other sources place the Colossus on a breakwater in the harbor.

Iron beams were embedded in the brick towers, and bronze plates attached to the bars formed the visible skin of the sculpture. Much of the iron and bronze was reforged from the various weapons Demetrius's army left behind, and the abandoned second siege tower was used for scaffolding around the lower levels during construction. Upper portions were built with the use of a large earthen ramp. The statue itself was over 110 feet tall, somewhere near the harbor entrance to Rhodes. After 12 years, in 280 B.C.E., the statue was completed. During construction, builders would pile mounds of dirt around the sides of the Colossus to aid in construction. To an observer it may have looked like a volcano-like sculpture. Upon completion all of the dirt was moved and the colossus was left to stand alone.

The "harbor-straddling Colossus" was a figment of later imaginations. Many older illustrations (above) show the statue with one foot on either side of the harbor mouth with ships passing under it:

> "The brazen giant of Greek fame, with conquering limbs astride from land to land"—*The New Colossus* (poem inscribed at the base of the Statue of Liberty).

In Shakespeare's play *Julius Caesar*, Cassius (I,ii,136–38) says of Caesar:

> Why man, he doth bestride the narrow world
> Like a Colossus, and we petty men
> Walk under his huge legs and peep about
> To find ourselves dishonorable graves

Shakespeare alludes to the Colossus also in *Troilus and Cressida* (Ch. 5) and in *Henry IV, Part 1* (Ch. 1).

While these fanciful images from poetry feed the misconception, mechanical engineers believe it was highly unlikely that the Colossus could have straddled the harbor (Maryon, 1956). Arguments against such an open-legged construction include:

- If the completed statue straddled the harbor, the entire mouth of the harbor would have been effectively closed during the entirety of the construction. Moreover, the ancient Rhodians did not have the means to dredge and re-open the harbor after construction.
- The statue fell in 224 B.C.E.: if it straddled the harbor mouth, it would have entirely blocked the harbor rather than falling on the land as described in the ancient sources.

- Even ignoring these objections, the statue was made of bronze, and an engineering analysis indicated that the Colossus could not have been built with its legs apart without collapsing from its own weight.

The construction

The Colossus was originally built as a victory monument by the people of Rhodes after they successfully resisted an attack by a powerful army in the aftermath of the division of Alexander the Great's empire. Alexander died at an early age in 323 B.C.E. without having time to put into place any plans for his succession. Fighting broke out among his generals, the *Diadochi*, with three of them eventually dividing up much of his empire in the Mediterranean area. During the fighting Rhodes had sided with Ptolemy, and when Ptolemy eventually took control of Egypt, Rhodes and Ptolemaic Egypt, forming an alliance that controlled much of the trade in the eastern Mediterranean.

Another of Alexander's generals, Antigonus I Monophthalmus, was upset by this turn of events. In 305 B.C.E. he had his son Demetrius Poliorcetes, also a general, invade Rhodes with an army of 40,000. However, the city was well defended, and Demetrius—whose name "Poliorcetes" signifies the "besieger of cities"—had to start construction of a number of massive siege towers in order to gain access to the walls. The first was mounted on six ships, but these were capsized in a storm before they could be used. He tried again with a larger, land-based tower named *Helepolis*, but the Rhodian defenders stopped this by flooding the land in front of the walls so that the rolling tower could not move. In 304 B.C.E. a relief force of ships sent by Ptolemy arrived, and Demetrius' army abandoned the siege, leaving most of their siege equipment.

To celebrate their victory, the Rhodians sold the equipment left behind for 300 talents and decided to build a colossal statue of their patron god, Helios. Construction was left to the direction of Chares, a native of Lindos in Rhodes, who had been involved with large-scale statues before. His teacher, the sculptor Lysippus, had constructed one 60-foot-high, bronze statue of Zeus at Tarentium. In order to pay for the construction of the Colossus, the Rhodians sold all of the siege equipment that Demetrius left behind.

The construction of the Colossus of Rhodes began in 292 BC and continued until 280 BC, ie a duration of work of only 12 years. For a statue more than 30m high and techniques of works of antiquity, it can be said that the site did not drag.The base of the construction was a marble base, a particularly solid material. On this base the workers stacked roughly cut stones to create the feet, then the legs, then the rest of the body. This formed a statue of unharmonious but solid form. Other workers then intervened to secure the stones of a band of iron tightly, at regular intervals, over the whole height of the statue. This strapping served as an intermediary, on which were fixed the bronze plates that dressed the statue.

Bronze is a mixture of iron and copper. The copper came from Cypriot mines from which the ore was mined. This work was particularly painful, as the galleries were not as secure as they are today. Once out it was heated to separate the copper from the rocks, then melted into ingots. It was these ingots that were transported to the site.

To make the bronze plates, the copper was first melted in large ovens, and the iron was then added to 10 to 20%. Then the mixture was transported in kinds of ladles that they used to distribute the metal in clay molds, flat molds to form sheets more or less thick according to the needs. The molds could be used several times, but did not have a long life. The next step was to remove the rough edges and then to polish the plates before transporting them to the site where they were recovered, hammered to the desired shape and then assembled on the iron structure and to the other plates by pegs. The plates of the feet and ankles were special, they were only molded (because of their shapes) and probably had to weigh heavier than the others to ensure the stability of the whole.

Thus the colossus of Rhodes was only covered with a thin film of bronze, its body being made of stone. Each plate was fixed on the iron frame and then on the neighboring plate. The colossus took pitch from day to day, until the top of the head was reached. Once finished, it was polished so that the Sun would make it shine as intensely as possible.

It should be noted that this construction technique is quite similar to that used for the construction of the Statue of Liberty in New York. But apart from the fact that the latter has a metallic structure (made by Gustave Eiffel), it is made of a copper plate held on the structure by iron rods. And for the record, know that when copper rubs on iron, it causes electricity, especially in a marine environment heavily loaded with salt. One can imagine that, like the statue of Liberty, the Colossus of Rhodes made its own electricity!

Materials

The choice of bronze was not made at random, it was on the contrary very studied. It is an alloy between copper and iron. Stronger than iron, it resists extreme weather conditions. It is therefore well suited to the manufacture of statues to be exposed to the outside, and in particular to sea air laden with salt.

Destruction

Alas, the Colossus of Rhodes is the marvel of the ancient world which had the shortest life: Barely 60 years old, almost. It must be said that the shape of the statue, its gigantism for the time and the means used for its construction contributed to make it ephemeral. A statue of 30m representing a character is inevitably more fragile than the pyramid of Cheops, the form of which is the most stable of the existing forms.

Rhodes was hit by an earthquake in 224 B.C.E. The statue snapped at the knees and fell over onto the land. Ptolemy III offered to pay for the reconstruction of the statue, but an oracle made the Rhodians afraid that they had offended Helios, and they declined to rebuild it. The remains lay on the ground as described by Strabo (xiv.2.5) for over eight hundred years, and even broken they were so impressive that many traveled to see them. Pliny the Elder remarked that few people could wrap their arms around the fallen thumb and that each of its fingers was larger than most statues. The pieces remained on the spot for 800 years, it is not known for what reason, but it is established that in 654 AD the Arabs, who invaded Rhodes, sold the bronze to a Syrian merchant. The metal was transported on the back of 900 camels and it is since that nothing remains of this statue.

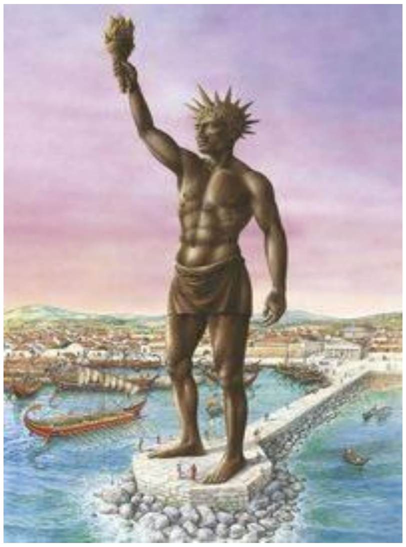
In 654 an Arab force under Muawiyah I captured Rhodes, and according to the chronicler Theophanes the Confessor, the remains were sold to a traveling salesman from Edessa, Mesopotamia. The buyer had the statue broken down, and transported the bronze scrap on the backs of nine hundred camels to his home. Pieces continued to turn up for sale for years, after being found along the caravan route.

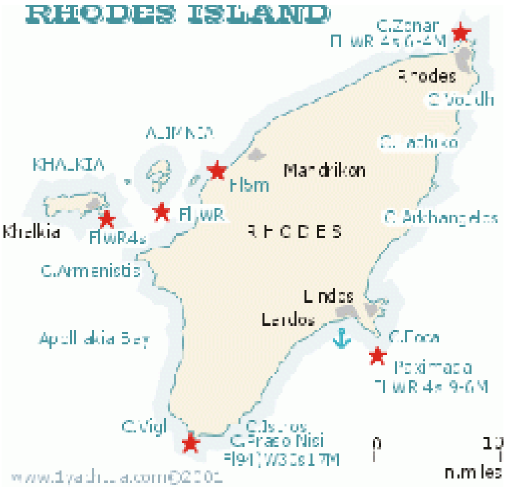
Symbolism

Beyond a desire to please the God Helios, the protector of Rhodes, the inhabitants knew that building the largest statue ever made on Earth would increase the prestige of their island. The political will to mark the spirits is evident and in this way joined the Lighthouse of Alexandria which was also built, besides serving as a lighthouse, to show the prestige of Egypt.

Otherwise we must know that the Colossus of Rhodes was one of the main inspirations of the Statue of Liberty. Since 2008, a series of as-yet-unrealized proposals to build a new Colossus at Rhodes Harbour have been announced, although the actual location of the original monument remains in dispute.

Some representations



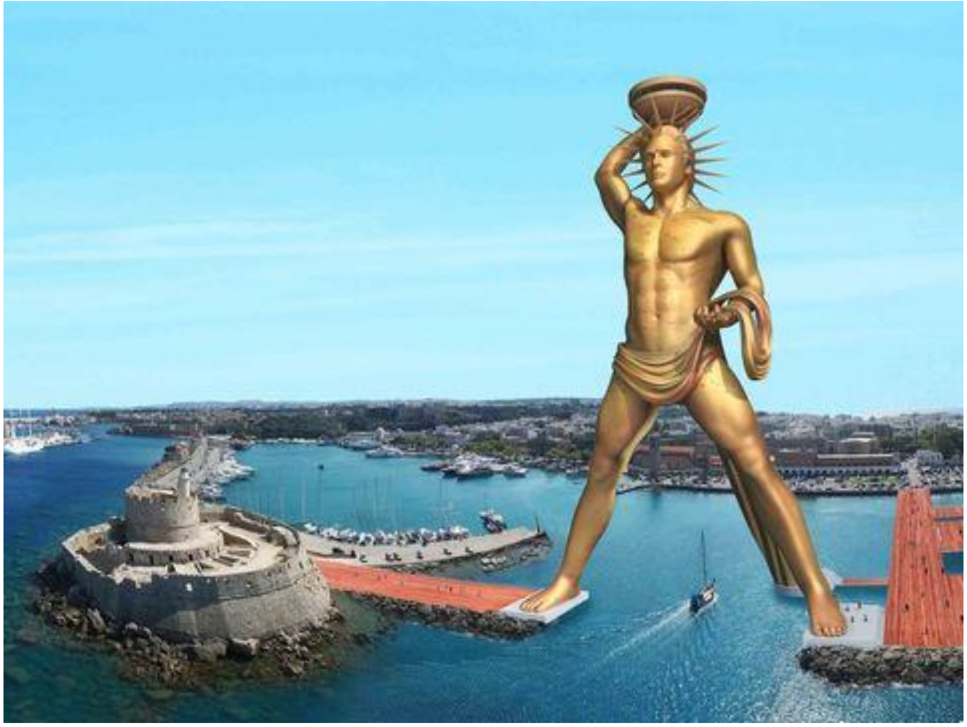


The Island of Rhodes, with the city of Rhodes at its northeast tip

- Media reports in 1989 initially suggested that large stones found on the seabed off the coast of Rhodes might have been the remains of the Colossus; however this theory was later rejected by most scholars.
- Sylvia Plath's poem "The Colossus" refers to the Colossus of Rhodes. Perhaps the most famous reference to the Colossus, however, is in the poem, "The New Colossus," by Emma Lazarus, written in 1883 and inscribed on a plaque at the Statue of Liberty in New York City's harbor.

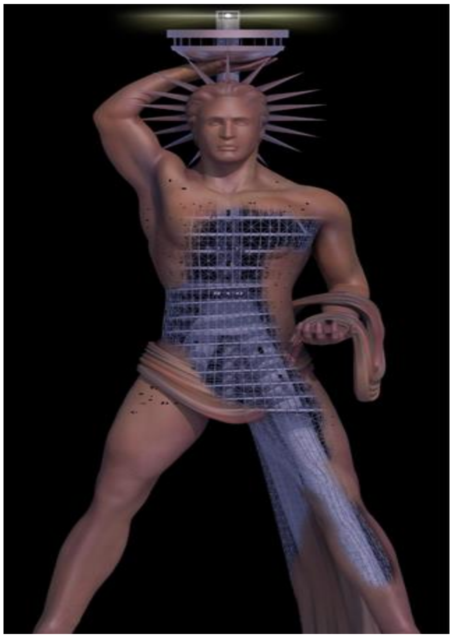
Not like the brazen giant of Greek fame,
With conquering limbs astride from land to land;
Here at our sea-washed, sunset gates shall stand
A mighty woman with a torch, whose flame
Is the imprisoned lightning, and her name
Mother of Exiles. From her beacon-hand
Glows world-wide welcome; her mild eyes command
The air-bridged harbor that twin cities frame.
"Keep, ancient lands, your storied pomp!" cries she
With silent lips. "Give me your tired, your poor,
Your huddled masses yearning to breathe free,
The wretched refuse of your teeming shore.
Send these, the homeless, tempest-tost to me,
I lift my lamp beside the golden door!"

There has been much debate as to whether to build a replica of the Colossus. Those in favor the idea say it would boost tourism in Rhodes greatly, but those against construction say it would cost too large an amount over US$134 million. This idea has been revived many times since it was first proposed in 1970.
In November 2008, it was announced that the Colossus of Rhodes was to be rebuilt. According to Dr. Dimitris Koutoulas, who is heading the project in Greece, rather than reproducing the original Colossus, the new structure will be a, "highly, highly innovative light sculpture, one that will stand between 60 and 100 metres tall so that people can physically enter it." The project is expected to cost up to €200m which will be provided by international donors and the German artist Gert Hof. The new Colossus will adorn an outer pier in the harbour area of Rhodes, where it will be visible to passing ships. Koutoulas said, "Although we are still at the drawing board stage, Gert Hof's plan is to make it the world's largest light installation, a structure that has never before been seen in any place of the world."[1]



COLOSSUS OF RHODES PROJECT

A collective of European architects has proposed to build a 21st-century version of the Colossus of Rhodes, the ancient Greek statue erected on the island of Rhodes in the 3rd century B.C. The new statue would stand 500-feet tall and serve as a cultural center as well as a lighthouse.



COLOSSUS OF RHODES PROJECT

Now, a group of architects, civil engineers, and archeologists from around Europe want to build a modern version of the statue, five times taller than the original. The project website describes "a contemporary 150-meters-tall building which would be used as a cultural center, as a library, an exhibition hall and a lighthouse."

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The designers want to cover the entire exterior with solar panels to power the enormous building. To ensure that the statue won't succumb to the same fate as the old Colossus, the engineering team says they will use "intelligent systems to prevent the consequences of earthquakes and wind forces." This amounts to building the statue as a tripod structure—two legs and a third support from the sash draped over the titan's arm and touching the ground—and placing a heavy steel support around the base to act as a counterbalance. A suspension system would allow the statue to rock back and forth.

This content is imported from YouTube. You may be able to find the same content in another format, or you may be able to find more information, at their web site.

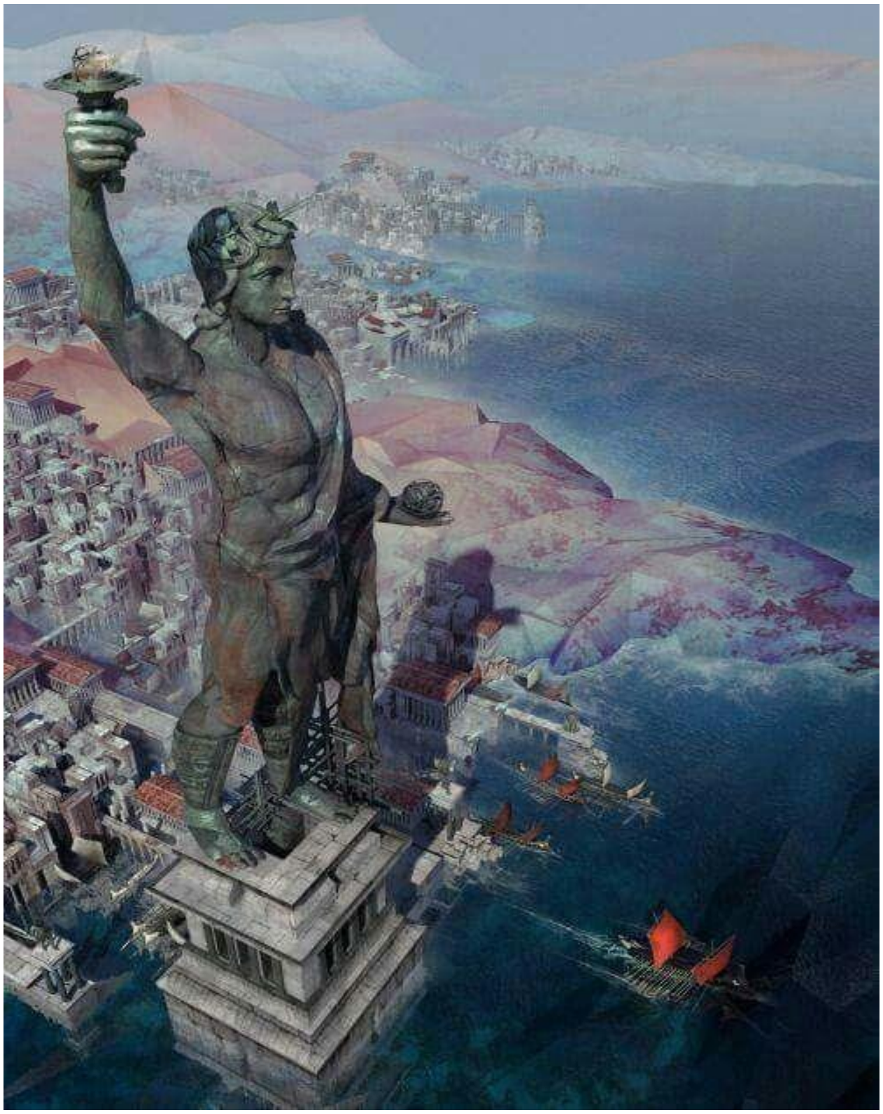
The Colossus of Rhodes Project says in its mission statement that one of the project's goals is to ease the economic hardships that have plagued Greece lately by both employing construction workers and attracting tourists to the island of Rhodes. The planned statue is intended to "put Rhodes again on the world map."

The backers estimate the cost of the statue at $283 million. They believe they can raise that much money through crowdfunding and private investments. It's an incredibly ambitious plan to be sure, and we're not convinced that it will ever get off the ground. But if the Colossus of Rhodes is resurrected, sailing into the island's harbor would be the experience of a lifetime—a real life version of cruising into Braavos.

The Rhodes Collosus as a light house

There is a fair deal of conversation to suggest that the Statute may have served as a light house and thereby fuelled a duel function. Numerous artistic depictions reveal the statute with a light source at the top and why noy?

It was standing in the harbor much like the statute of Liberty does today and for a few years the liberty statute too served as a light becon.



REFERENCES

1. There's a Plan To Rebuild the Colossus of Rhodes,BY JAY BENNETT, 2016

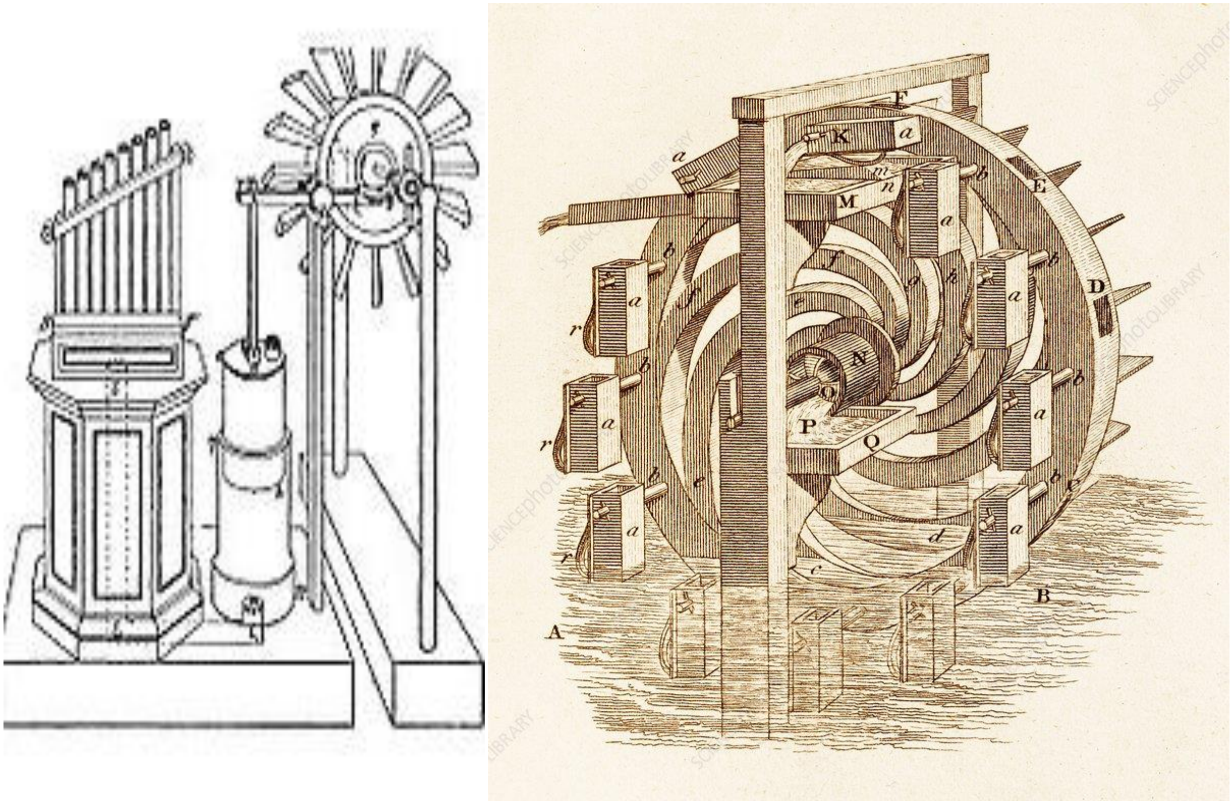
CHAPTER VII

Harnessing the Wind and Water by TOWERS

“The energy of wind has been exploited for thousands of years. The oldest applications of wind energy include extracting water from wells, making flour out of grain, and other agricultural applications. In recent times, the use of wind energy has evolved to, primarily, generation of electricity.The field of wind energy blossomed in 1970s after the oil crisis, with a large infusion of research money in the United States, Denmark,and Germany to find alternative sources of energy. By the early 1980s,incentives for alternative sources of energy had vanished in the United States and, therefore, the wind energy field shrank significantly. Investments continued in Europe and, until recently, Europe led in terms of technology and wind capacity installations”
Pramod Jain, https://epdf.pub/wind-energy-engineering.html

Wind is everywhere and nowhere. Wind is the circulatory system of the earth, and its nervous system, too. Energy and information flow through it. It brings warmth and water, enriches and strips away the soil, aerates the globe. Wind shapes the lives of animals, humans among them. Trade follows the path of the wind, as empire also does. Wind made the difference in wars between the Greeks and Persians, the Mongols and the Japanese. Wind helped to destroy the Spanish Armada. And wind is no less determining of our inner lives: the föhn, mistral, sirocco, Santa Ana, and other "ill winds" of the world are correlated with disease, suicide, and even murder.Wind is caused by the uneven heating of the earth's surface, which creates different temperature and pressure areas known as anticyclones and depressions. As the atmospheric forces try to balance, air masses move from anticyclones to areas of depression. The larger the depression, the stronger the wind.[1]

Wind force has long been used to propel boats and drive windmills. Today it is being converted into electricity thanks to wind turbines. The wind’s energy has been harnessed for centuries. Wind turbines are the machines that convert this energy into electricity. Equipped with state-of-the-art technology, the turbines operate like mini power plants. A windmill is a structure that converts wind power into rotational energy by means of vanes called sails or blades, specifically to mill grain (gristmills), but the term is also extended to windpumps, wind turbines and other applications. Windmills were used throughout the high medieval and early modern periods; the horizontal or panemone windmill first appeared in Greater Iran during the 9th century, the vertical windmill in northwestern Europe in the 12th century.



A 19th-century reconstruction of Heron's wind-powered organ description.Persian wheel (right)

Hero of Alexandria (Heron) in first-century Roman Egypt described what appears to be a wind-driven wheel to power a machine. His description of a wind-powered organ is not a practical windmill, but was either an early wind-powered toy, or a design concept for a wind-powered machine that may or may not have been a working device, as there is ambiguity in the text and issues with the design. Another early example of a wind-driven wheel was the prayer wheel, which is believed to have been first used in Tibet and China, though there is uncertainty over the date of its first appearance, which could've been either circa 400, the 7th century, or after the 9th century.

Hooper's Mill, Margate, Kent, an eighteenth-century European horizontal windmill

The first practical windmills were panemone windmills, using sails that rotated in a horizontal plane, around a vertical axis. Made of six to 12 sails covered in reed matting or cloth material, these windmills were used to grind grain or draw up water. These windmills are recorded by Persian geographer Estakhri in the 9th century as being operated in Khorasan (Eastern Iran and Western Afghanistan). The authenticity of an earlier anecdote of a windmill involving the 7th-century caliph Umar (634–644) is questioned on the grounds that it is recorded only in the 10th century. Such windmills were in widespread use across the Middle East and Central Asia, and later spread to Europe, China and India from there. By the 11th century, the vertical-axle windmill had reached parts of Southern Europe, including the Iberian Peninsula (via Al-Andalus) and the Aegean Sea (in the Balkans). A similar type of horizontal windmill with rectangular blades, used for irrigation, can also be found in thirteenth-century China (during the Jurchen Jin dynasty in the north), introduced by the travels of Yelü Chucai to Turkestan in 1219.

Vertical-axle windmills were built, in small numbers, in Europe during the 18th and nineteenth centuries, for example Fowler's Mill at Battersea in London, and Hooper's Mill at Margate in Kent. These early modern examples seem not to have been directly influenced by the vertical-axle windmills of the medieval period, but to have been independent inventions by 18th-century engineers.

The power of the wind was first harnessed by sailors, who were able to understand lift and harness the winds power through sails. This knowledge led to the development of the first vertical axis sail-type windmill used by the ancient Persians and Chinese for grinding grain and pumping water.

Fowlers Mill UK

They consisted of vanes called sails or blades that when prompted to turn by the wind, converted the wind’s energy into rotational energy that could be utilized.

Early European windmills with horizontal axis systems were the foundation for current wind turbine technology used for energy production.

This article is going to discuss the history of windmills and how they advanced to modern designs, as well as how they work.

Early history: There is no concrete evidence on who exactly was the first to invent the windmill, whether it was the Chinese or the Persians is up for debate. Regardless, both cultures began using this technology around the same time for the same purposes.

Some believe that the windmill technology was brought to Northern Europe as a result of the crusades, however their horizontal axis design rather than the vertical axis system, makes it just as likely that the Europeans discovered their windmill independently. The first existing illustrations from 1270 A.D. show blue-prints of the post mill type of windmill.

The post mill was composed of a four bladed mill mounted onto a central post, which used wooden cog-and-ring gears to covert the motion of the horizontal shaft to vertical motion that turned a grind stone. According to the Illustrated History of Wind Development, the wooden cog-and-ring gear was used by Vitruvius, an engineer of the Augustan Age, to develop the first horizontal axis water wheel.

The tower mill design is believed to have come into existence around the late 1300s, with the earliest known illustration being of a Normandy Mill between 1430 and 1440. The tower mill was made with sloping walls, a cap that could be rotated, a horizontal wind shaft, and vertical sails.

The smock mill, developed by the Dutch in 1526 based on the tower mill, is a vertical tapered tower with four to six sides topped with a cap that rotates to bring the sails into the wind. The smock mill was named from its resemblance to the smocks worn by farmers at the time.

Over the next 500 years windmills gained many diverse applications beyond just water-pumping and grinding grain including irrigation, drainage pumping, saw milling of timber, and processing tobacco, spices, cocoa, paints, and dyes.

Mechanical water pumping mills were first developed in the United States in 1854. These mills originally consisted of four wooden blades, with steel blades coming into existence in 1870.

More than six million mechanical wind mills were installed in the United States between 1850 and 1970. Their main applications were for stock watering and water for farm houses. Very large windmills were used to pump water for steam trains.

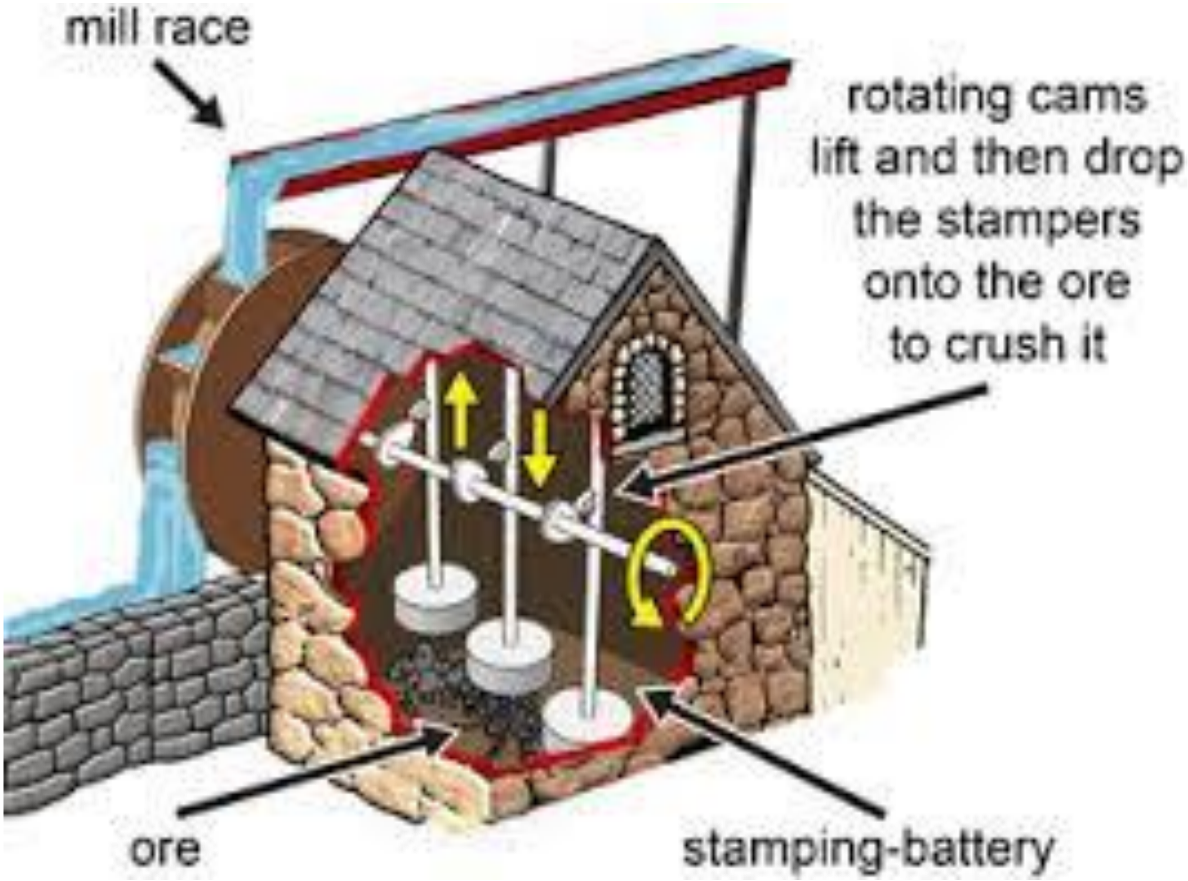
The first windmill to generate electricity was invented in 1888 by an Ohio-based engineer named Charles Brush. The windmill could generate up to 12 kilowatts of electricity and was a sixty foot post mill with a 56 foot rotor.

In today’s society windmills used to generate electricity are referred to as wind turbines.

The wind turbine market evolved from the 1 to 25 kilowatt range for domestic and agricultural practices, to intermediate-scale machines in the 50 to 600 kilowatt range for interconnected utility wind farm applications between the years of 1973 and 1986.

Over this time period, more than 20 different designs where engineered and tested, most proving to be unfeasible and inefficient.

Wind turbines evolved from the four bladed systems first created in the United States, to two bladed systems, and finally to the three bladed systems commonly seen in wind farms today.


mill race
rotating cams lift and then drop the stampers onto the ore to crush it
ore
stamping-battery

Working of Mills: The earliest documented windmills were vertical axis systems, with vertical sails made from reeds or wood that was attached by horizontal struts to a vertical shaft with a stone for grinding purposes. The first windmill to appear in Europe was the post mill with a horizontal axis system, with a four-bladed mill attached to a central post.

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Both the tower and post mills were originally designed to be manually oriented into the wind by pushing a lever located on the back of the mill. In 1745, Edmund Lee invented the windmill fan tail, which was mounted on the rear of the mill at right angles to the sails automatically turning the cap to bring the sails into the wind.

Smock mills are similar to tower mills differing mainly in their appearance, in which smock mills were octagonal or hexagonal with their six to eight sides, rather than circular. Smock mills have the same rotating cap design as the tower mills, but were typically much larger.

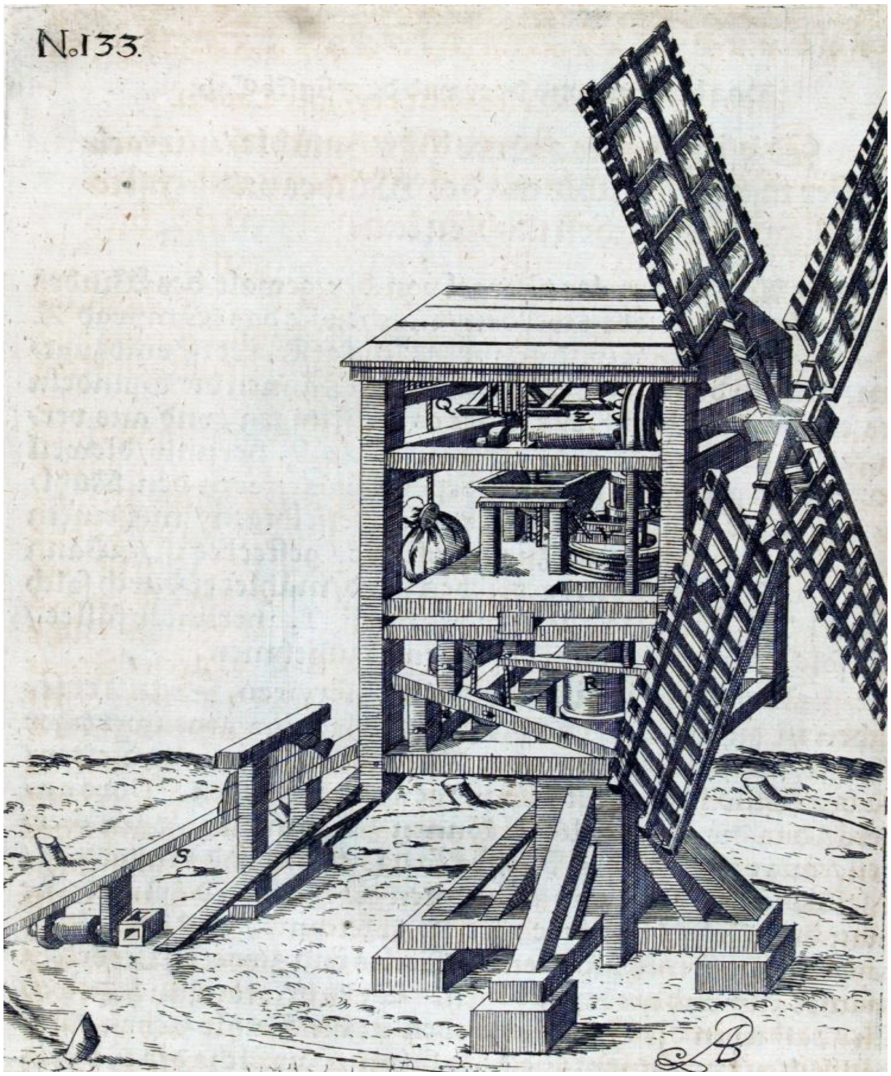
The first mechanical mills that appeared in the United States had four wooden blades that resembled paddles, and most were equipped with "tails" that oriented them into the wind. However, some of these mechanical mills were designed to operate downwind, called weather-vaning mills.

Some mechanical mills sported speed control provided by hinged blades that folded back in high winds reducing the thrust, by reducing the rotor capture area. When steel blades where introduced they required a reduction gear to compensate for their high speed, so that the standard reciprocal pumps were at the right speed for the mill to function properly.

The three-bladed turbine systems commonly seen today, function in much the same way as the original post mills. Wind turns two or three blades around a rotor that is connected to a main shaft that spins a generator to create electricity.

The rotor, which is the blades and hub combined, are mounted 100 feet or more above the ground to take advantage of faster, less turbulent wind. The rotor is attached to a pitch system that turns the blades out of the wind to control the rotor speed.

When winds are too high or too low to produce electricity the pitch system prevents the rotor from turning.



The pitch system is connected to a low speed shaft that turns at about 30-60 rotations per minute. The low speed shaft is connected to the gear box which turns the low rotational speeds into the high rotational speeds of 100-1800 rpms required by the generator, which is attached to the gearbox, to produce electricity.Moat important feature of the tower mill was a cap (roof) that could pivot in response to changing wind patterns. Unlike the post mill where you had to move the entire structure to orient the mill, only the cap had to be moved in the tower mill.

In the 21st century we are starting to see many advances in the wind power industry including bladeless technologies and generators that do not require a gear box. But they are still in their infancies.

Wind power is one of the best solutions to the world's increasing energy needs, because it is clean and does not produce toxic emissions to generate the electricity, unlike fossil fuels.

windmill's have come a long way since there conception, and modern advances in turbine technology are proving wind power to be an environmentally friendly substitute for fossil fuels.

The Romans constructed mills for use in agriculture, mining and construction. Around the 3rd century BCE, the first mills were used to grind grain. Later developments and breakthroughs in milling technology expanded their use to crushing ores in mining and such construction activities as cutting wood and marble. Mills became an important part of the Roman economy, decreasing the reliance on human labour, and dramatically increasing productivity and efficiency in many sectors of the Roman economy.

MILLS USED IN AGRICULTURE

Hand-driven Mills

In the agricultural sector, mills allowed for the production of large quantities of flour which was essential to bread production. Before mills were ever invented, humans ground cereals with the use of saddle querns which consisted of a rounded stone pressed manually against a flat stone bed. The first significant innovation in milling came in the late 5th century BCE in Greece, with the introduction of the first milling machine: the Olynthus Mill, also known as the hopper mill. The Olynthus Mill consisted of rectangular-shaped lower and upper stones. The top stone had a long handle and was moved in reciprocal fashion from side to side. The mill also had a hollow cavity (or hopper) with a narrow slot at its centre through which the miller fed the grain.

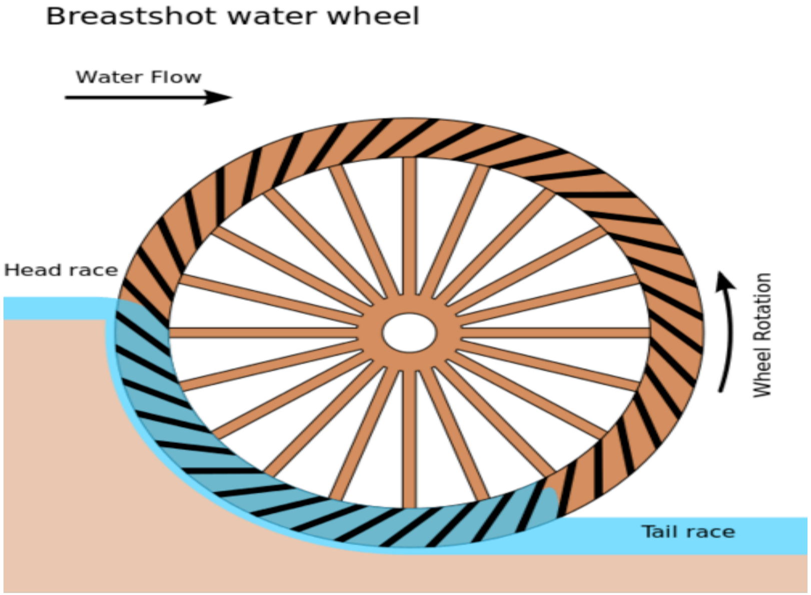
A Pompeii Bakery.by Penn State Libraries Pictures Collection (CC BY-NC-SA)

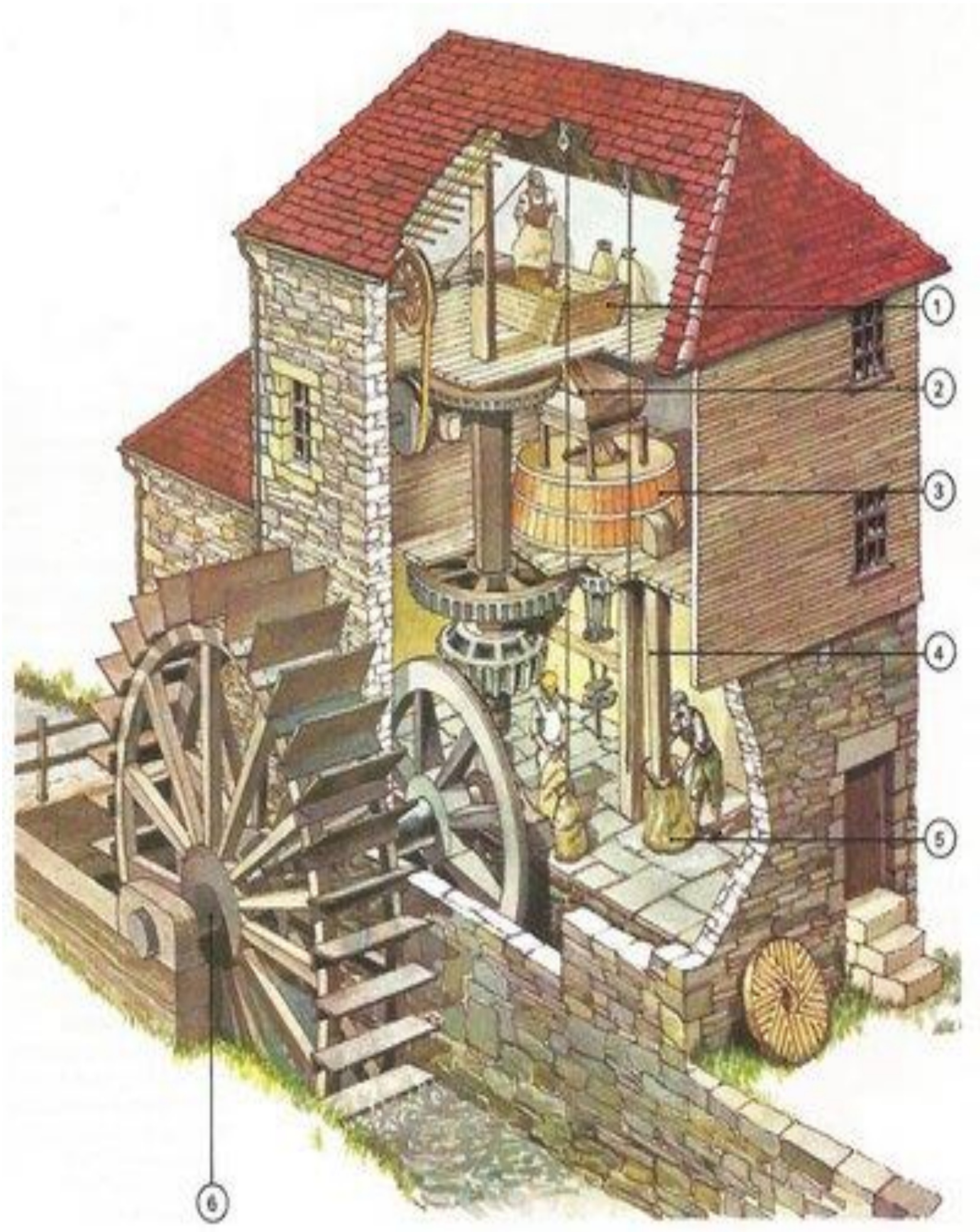
Animal-driven Mills

Rotary mills were an improvement over the Olynthus Mill in that cranks could be attached to a beast for grinding. The animal-driven rotary mill appeared around the 3rd century BCE in Italy, one of the best examples being the Pompeian mill which is often associated with the rise of commercial bakeries. Such Pompeian mills were driven by two donkeys harnessed to a wooden frame. The mill consisted of two parts: the lower stone (the *meta*) and the upper stone (the *catillus*), both made of strong volcanic rock. The upper concave and hour-glass shaped *catillus* was turned by donkeys. It had a hole through its centre and a hopper at its top through which the miller poured the grain. This stone rotated against the lower *meta* stone which was slightly convex and immobile. The animal-driven rotary mill saved humans from the drudgery of milling and significantly increased the flour output and quality as donkeys could drive the mill for hours at a time.

Water-driven Mills

The watermill was another significant invention which, according to most historians, came later in the last century BCE, or slightly earlier. In this version of the mill, water striking paddles drove the upper catillus stone with much greater power than had been available from animals. Watermills could therefore produce even greater amounts of flour.





Many engineering challenges had to be solved for their construction. For example, a constant supply of running water was needed, with the ability to turn it off during inspections and repairs. This was addressed with mill-channels, sometimes several kilometres long, with a system of reservoirs and sluice-gates that could limit or cut off the amount of water admitted to the paddle wheels. In some cases, aqueducts rather than canals ensured a constant water supply.

Another technical challenge was the conversion of the circular movement of the waterwheel to a rotation of the upper *catillus* or "runner stone" outside the water stream. In the horizontal-wheeled mill version, this movement was transferred directly to the runner stone by means of a vertical shaft. In the vertical-wheeled watermill, the vertical, circular movement of the waterwheel was converted to a horizontal rotation through the use of a right-angle gear. The right-angle gear, invented about 270 BCE, was a transmission system consisting of two cogwheels which increased the velocity of the runner stone, thereby, generating additional power.

There were three variants of the vertical-wheeled mill:

- the undershot mill (water hitting the bottom of the wheel)
- the overshot (water hitting the paddles at the top of the wheel)
- the breastshot water wheel (water hitting the middle of the wheel)

The undershot mill was the simplest, earliest, and most common application of the three.

To justify a watermill's construction costs there had to be a large enough concentration of people (between 200 and 400 inhabitants in the surrounding area). When the population's concentration was even greater than this, clusters of mills were built, such as the Janiculum mills (early 3rd century CE) in Rome or the Barbegal complex (early 2nd century CE) in southern France. At the Barbegal complex, for example, an aqueduct could supply water to sixteen overshot wheels while on the slope of the Janiculum hill in Rome, a large number of mills also used aqueduct water to produce flour on an industrial scale from the 3rd through to the 6th century CE.

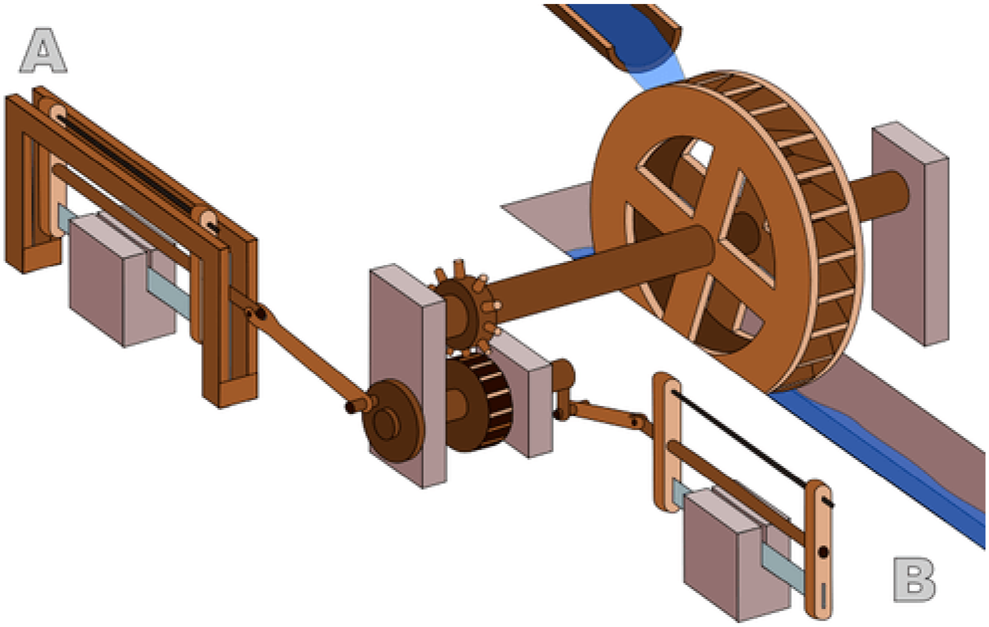
Stamp mills were used in mining to crush ore from deep deposits into small pieces before further processing. The metal ores needed to be crushed down to a pea or walnut size before it could be smelted. At times, the mills were also used in metal working after the completion of the smelting while the metal was red hot. The presence of stone anvils with marks from trip-hammers at Dolaucothi and other ancient Roman mining sites is proof that stamp mills were widely used in this way to pound extracted ore.

These stamp mills consisted of waterwheels, cams and trip-hammers (mola). They first appeared in Greece around the 3rd century BCE, and then spread across Italy throughout the first century CE. Before this invention, such crushing of ores was done manually, which required a lot of men and effort. As was the case with grain mills, these stamp mills saved greatly on manpower, while also greatly increasing the speed of ore processing. Stamp mills were mostly used in mining applications, but at times were also used to pound and hull grain.

Because water powered these stamping machines, aqueducts were often constructed near mining sites. For example, at the Dolaucothi mines in Wales, or in the Rio Tinto in Spain, long aqueducts were built to power a number of such stamp mills. There, aqueduct water was used as well in ore extraction techniques known as "hushing" and "ground sluicing". Some metal ores such as gold needed to be finely ground in order to release the tiny metal particles from surrounding rock, salts and sands. For this purpose, the Romans constructed watermills similar to the previously mentioned agricultural ones, but these had even harder grinding stones.

Construction Mills:

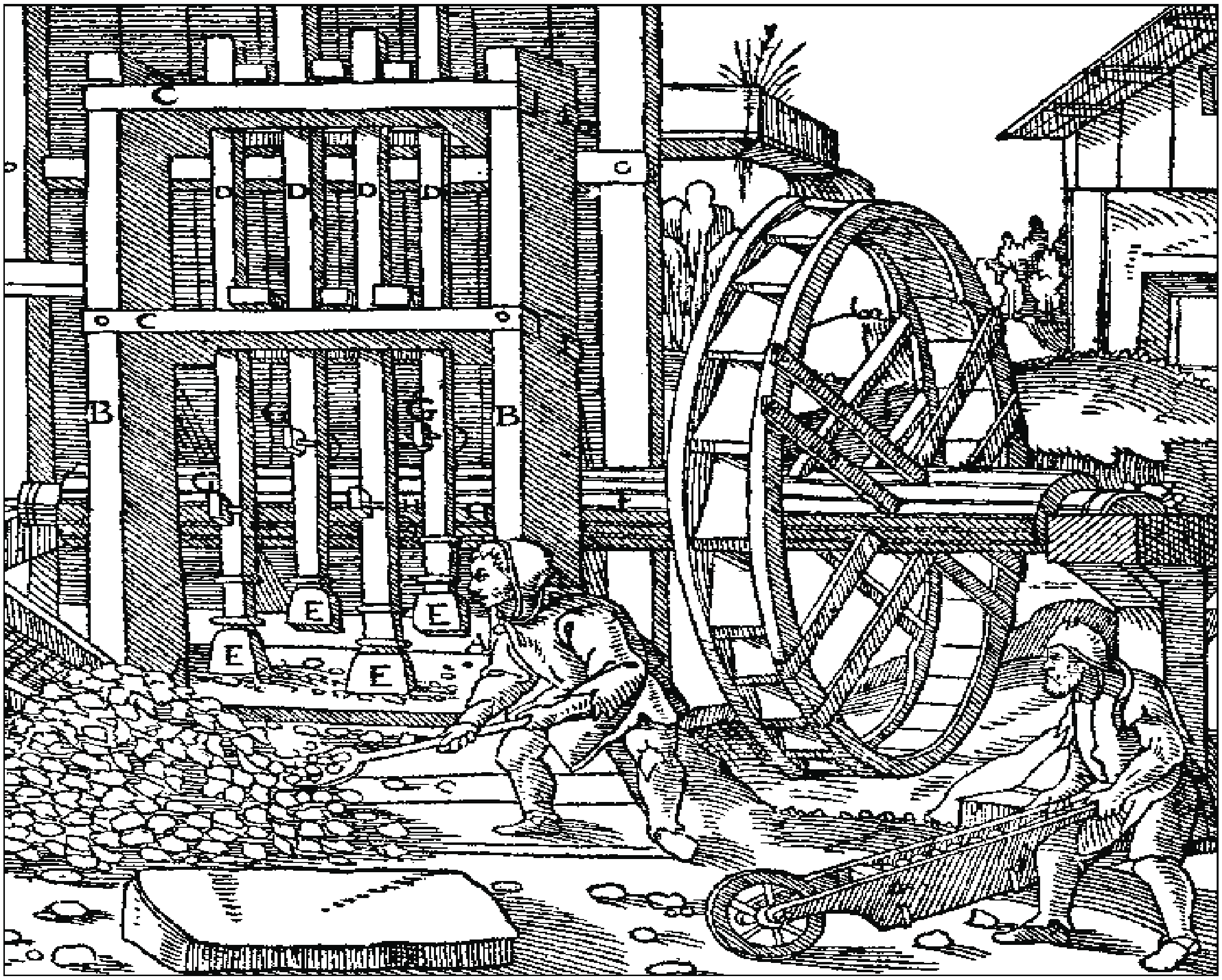
The sawmill was another example of a surprisingly-sophisticated machine which consisted of a reciprocating saw powered by a waterwheel. It could cut large amounts of wood or stone, thereby saving enormous amounts of effort and labour. The waterwheel was connected to a rod linked to one or multiple crank-activated saws. The earliest known sawmill was the Hierapolis mill dating back to 250-300 CE. It was the earliest known machine to use a crank with a connecting rod mechanism. A relief on the sarcophagus of Marcus Aurelius Ammianos (dating back to 250-300 CE), in the ancient city of Hierapolis near modern-day Pamukkale in Turkey, gives a clear representation of how it functioned.



Roman Sawmill. by Chris (CC BY)

Sawmills were also commonly used to cut marble. A Roman poet called Ausonius writes in an epic poem about the river Moselle in Germany in the late 4th century CE and describes the shrieking sound of a water-powered sawmill used to cut marble. These sawmills were also used to cut various other types of stones. Sawmills dating from the 6th century CE were also found in Gerasa (in modern-day Jordan) and Ephesus (in modern-day Turkey). Therefore, it is safe to say that they were used throughout the Roman empire for various uses.

The invention of mechanically-driven milling technology, and later of watermills, decreased reliance on human labour and greatly improved productivity in many sectors of the Roman economy, thereby, improving the daily lives of Romans. Watermills such as the Janiculum mills in Rome allowed for the production of flour and bread on industrial scales. Stamp mills accelerated ore processing at mining sites throughout the empire, while sawmills allowed for marble and other stones to be cut precisely and at record speeds. Roman milling technology progressed from manual to animal-driven rotary mills in the 1st century BCE, and then to the more complex water-powered and crank activated sawmills of the 3rd century CE. Many of the principles used in the construction of these early machines are still applied to modern mill designs today. Such mills are additional examples of the ingenuity, impressive design, and manufacturing skills of the Romans.



Water powered stamp mill in Germany- 16 th century

A tower mill is a type of vertical windmill consisting of a brick or stone tower, on which sits a wooden 'cap' or roof, which can rotate to bring the sails into the wind.[1][2][3][4][5]

This rotating cap on a firm masonry base gave tower mills great advantages over earlier post mills, as they could stand much higher, bear larger sails, and thus afford greater reach into the wind. Windmills in general had been known to civilization for centuries, but the tower mill represented an improvement on traditional western-style windmills. The tower mill was an important source of power for Europe for nearly 600 years from 1300–1900, contributing to

25 percent of the industrial power of all wind machines before the advent of the steam engine and coal power.

It represented a modification or a demonstration of improving and adapting technology that had been known by humans for ages. Although these types of mills were effective, some argue that, owing to their complexity, they would have initially been built mainly by the most wealthy individuals.

Alford Windmill

History: The origins of the tower mill can be found in a growing economy of Europe, which needed a more reliable and efficient form of power, especially one that could be used away from a river bank. Post mills dominated the scene in Europe until the 19th century when tower mills began to replace them in such places as Billingford Mill in Norfolk, Upper Hellesden Mill in Norwich, and Stretham Mill in Cambridgeshire.

The tower mill originated in written history in the late 13th century in western Europe; the earliest record of its existence is from 1295, from Stephen de Pencastor of Dover, but the earliest illustrations date from 1390. Other early examples come from Yorkshire and Buckinghamshire. Other sources pin its earliest inception back in 1180 in the form of an illustration on a Norman deed, showing this new western-style windmill.[10] The Netherlands has six mills recorded before the year 1407. One of the earliest tower mills in Britain was Chesterton Mill, Warwickshire, which has a hollowed conical base with arches. The large part of its development continued through the Late Middle Ages, towards the end of the 15th century tower mills began appearing across Europe in greater numbers.

The tower mill also was seen as a cultural object, being painted and designed with aesthetic appeal in mind. Styles of the mills reflected on local tradition and weather conditions, for example mills built on the western coast of Britain were mainly built of stone to withstand the stronger winds, and those built in the east were mainly of brick.

In England around 12 eight-sailers, more than 50 six- and 50 five-sailers were built in the late 18th century and 19th century, half of them in Lincolnshire.

Design: The advantage of the tower mill over the earlier post mill is that it is not necessary to turn the whole mill ("body", "buck") with all its machinery into the wind; this allows more space for the machinery as well as for storage. However, select tower mills found around Holland were constructed on a wooden frame so as to rotate the entire foundation of the mill along with the cap. These towers were often constructed out of wood rather than masonry as well.[13][14] A movable head which could pivot to react to the changing wind patterns was the most important aspect of the tower mill. This ability gave the advantage of a larger and more stable frame that could deal with harsh weather. Also, only moving a cap was much easier than moving an entire structure.

Indian water mill from Rajasthan.Still operational

In the earliest tower mills the cap was turned into the wind with a long tail-pole which stretched down to the ground at the back of the mill. Later an endless chain was used which drove the cap through gearing. In 1745 an English engineer, Edmund Lee, invented the windmill fantail – a little windmill mounted at right angles to the sails, at the rear of the mill, and which turned the cap automatically to bring it into the wind.

Like other windmills tower mills have normally four blades. To increase windmill efficiency millwrights experimented with different methods:

- automated patent-sails instead of cloth spread type sails didn't need the sail cross to be stopped to spread or remove the cloth sails because they altered the surface from inside the mill by means of a controlling gear.
- more than four blades to increase the sail surface.

Therefore, engineer John Smeaton invented the cast-iron *Lincolnshire cross* to make sail-crosses with five, six, and even eight blades possible. The cross was named after Lincolnshire where it was most widely used.

There are several components to the tower mill as it was in the 19th Century in Europe in its most developed stage, some elements such as the gallery are not present in all tower mills:[16]

- Stock – the arm that protrudes from the top of windmill holding the frame of the sail in place, this is the main support of the sail and is usually made of wood.
- Sail – the turning frame that catches the wind, attached and held by the stock. The traditional style found on most tower mills is a four-sail frame, however in the Mediterranean model there is usually an eight-sail frame. An example of this in St. Mary's Mill on the Isle of Sicilly constructed in 1820.
- Windshaft – A particularly important part of the sail frame, the windshaft is the cylindrical piece that translates the movement of the sail into the machinery within the windmill.
- Cap – The top of the tower that holds the sail and stock, this piece is able to rotate on top of the tower.
- Tower – Supports the cap, the main structure of the tower mill.
- Floor – Base level of the tower inside, usually where grain or other products are stored.
- Gallery – Deck surrounding the floor outside the tower to provide access around the tower mill if it is raised, not present in all tower mills. The gallery allowed access to the sails for making repairs because they could not be easily reached from the ground in larger mills.[17]
- Frame – Sail design that forms the outline of the sail, usually a meshed wood design that then is covered in cloth. The Mediterranean design is different in that there are several sails on the sail-frame and each supports a draped cloth and there is no wooden frame behind it.
- Fantail – Orientation device that is attached to the cap, allowing it to rotate to keep the sails in the direction of the wind.
- Hemlath – Thick wooden sailbar on the side of the frame that keeps the narrower sailbars inside the sail.
- Sailbar – Elongated piece of wood that forms a sail.
- Sail cloth – Cloth attached to a sail that collects wind energy; a large sail cloth is used for weak winds and a small sail cloth for strong winds.

The tower mill was more powerful than the water mill, able to generate roughly 20 to 30 horsepower. There were many uses that the tower mill had aside from grinding corn. Tower

Mills fueled a society that was steadily growing in its need for power by providing a service to other industries as well.

- The production of pepper and other spices
- Lumber companies used them for powering sawmills
- Paper companies used to change wood pulp into paper

Other sources argue against this claiming there is no real evidence, specifically, of tower mills doing these things.

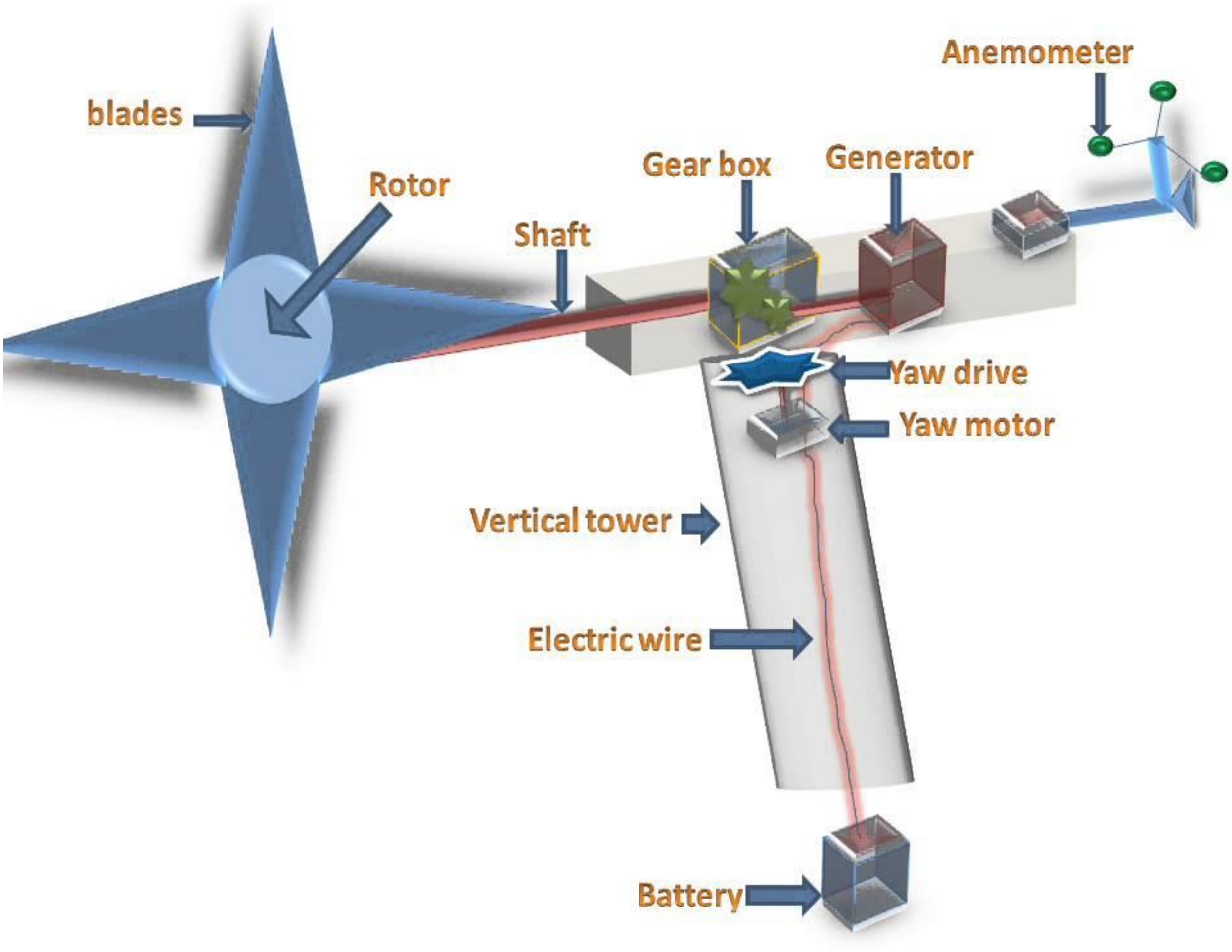
Schiedam, Netherlands with the highest mill being De Nolet (built in 2006 as a "generator mill" producing electricity and named after the local Nolet distilling family the mill belongs to, 140 ft / 42.5 metres to cap) and *De Noord* (*The North*, corn mill of 1803), 109 ft / 33.5 metres to cap) both in working order.

England's tallest tower mill is the nine-storeyed Moulton Windmill in Moulton, Lincolnshire, with a cap height of 97.5 ft / 30 metres. Since 2005 the mill has a new white rotatable cap with windshaft and fantail in place, the stage was erected during 2008 and new sails were fitted on 21 November 2011 to complete the restoration of the mill.

Horizontal Mill working

In the Netherlands windmills named *torenmolens* (tower mills) have a compact-built, cylindric or only slightly conical tower. In the southern Netherlands four mills of that type (Dutch definition) survived, the oldest one built before 1441. The cap of three of those mills is turned by a luffing gear built in the cap. Older types of the tower mill could be found on castles, fortresses or city walls with a fixed cap since the 14th century, and are still be found around the Mediterranean Sea. They were built with the sails facing the prevailing wind direction.

Tower mills were very expensive to build with estimates suggesting almost twice that of post mills, which is in part why they were not very prevalent until centuries after invention. Sometimes these mills were even built on the sides of castles and towers in fortified towns to make them resistant to attacks. Some tower mills were still in operation well into the 20th century in the southern parts of the UK.



The horizontal-axis or vertical windmill (so called due to the plane of the movement of its sails) is a development of the 12th century, first used in northwestern Europe, in the triangle of northern France, eastern England and Flanders. It is unclear whether the vertical windmill was influenced by the introduction of the horizontal windmill to Southern Europe in the preceding century.

The earliest certain reference to a windmill in Northern Europe (assumed to have been of the vertical type) dates from 1185, in the former village of Weedley in Yorkshire which was located at the southern tip of the Wold overlooking the Humber Estuary. A number of earlier, but less certainly dated, 12th-century European sources referring to windmills have also been found. These earliest mills were used to grind cereals.

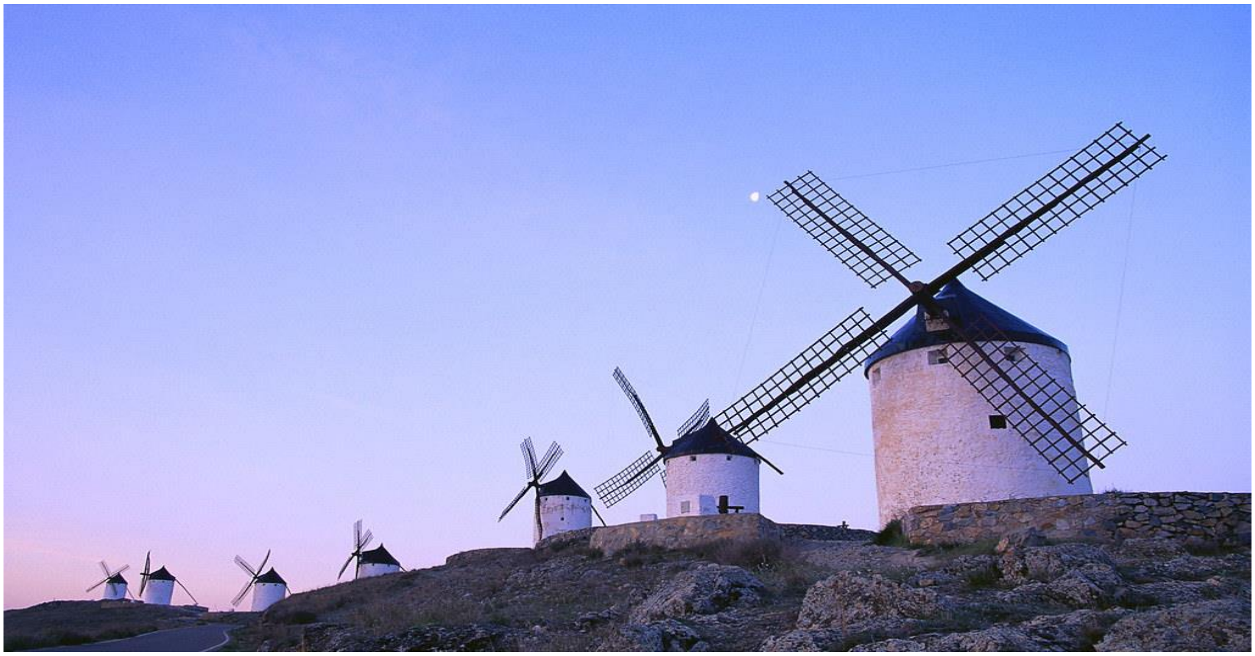
Post mill

The evidence at present is that the earliest type of European windmill was the post mill, so named because of the large upright post on which the mill's main structure (the "body" or "buck") is balanced. By mounting the body this way, the mill is able to rotate to face the wind direction; an essential requirement for windmills to operate economically in north-western Europe, where wind directions are variable. The body contains all the milling machinery. The first post mills were of the sunken type, where the post was buried in an earth mound to support it. Later, a wooden support was developed called the trestle. This was often covered over or surrounded by a roundhouse to protect the trestle from the weather and to provide storage space. This type of windmill was the most common in Europe until the 19th century, when more powerful tower and smock mills replaced them.

Hollow-post mill

In a hollow-post mill, the post on which the body is mounted is hollowed out, to accommodate the drive shaft. This makes it possible to drive machinery below or outside the body while still being able to rotate the body into the wind. Hollow-post mills driving scoop wheels were used in the Netherlands to drain wetlands from the 14th century onwards.

Tower mill



Tower mills in** Consuegra**, Spain

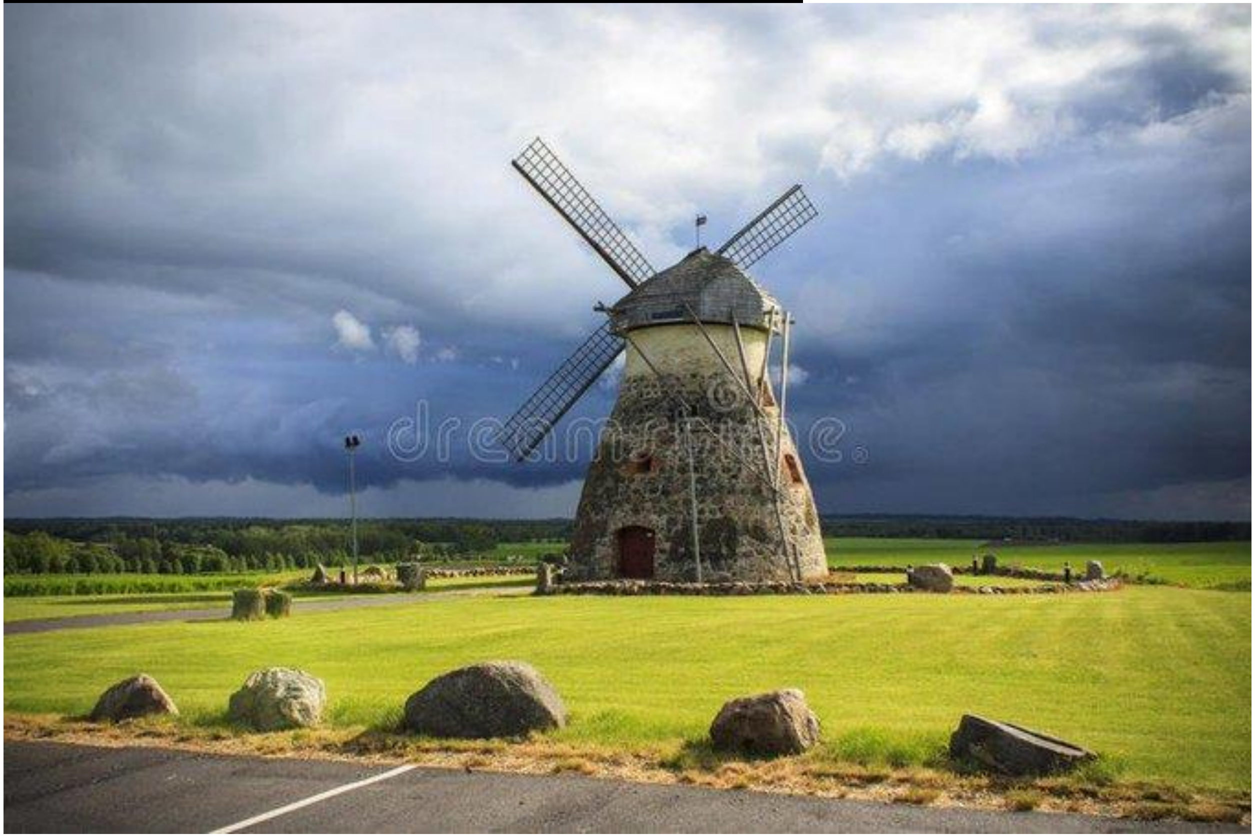
By the end of the 13th century, the masonry tower mill, on which only the cap is rotated rather than the whole body of the mill, had been introduced. The spread of tower mills came with a growing economy that called for larger and more stable sources of power, though they were more expensive to build. In contrast to the post mill, only the cap of the tower mill needs to be turned into the wind, so the main structure can be made much taller, allowing the sails to be made longer, which enables them to provide useful work even in low winds. The cap can be turned into the wind either by winches or gearing inside the cap or from a winch on the tail pole outside the mill. A method of keeping the cap and sails into the wind automatically is by using a fantail, a small windmill mounted at right angles to the sails, at the rear of the windmill. These are also fitted to tail poles of post mills and are common in Great Britain and English-speaking countries of the former British Empire, Denmark, and Germany but rare in other places. Around some parts of the Mediterranean Sea, tower mills with fixed caps were built because the wind's direction varied little most of the time.

Smock mill

The smock mill is a later development of the tower mill, where the masonry tower is replaced by a wooden framework, called the "smock", which is thatched, boarded or covered by other materials, such as slate, sheet metal, or tar paper. The smock is commonly of octagonal plan, though there are examples with different numbers of sides. The lighter weight than tower mills make smock mills practical as drainage mills, which often had to be built in areas with unstable subsoil. Smock mills originated for drainage, but are also used for other purposes. When used in a built-up area it is often placed on a masonry base to raise it above the surrounding buildings.It consists of a sloping,horizontally weatherboarded or thatched tower, usually with six or eight sides. It is topped with a roof or cap that rotates to bring the sails into the wind. This type of windmill got its name from its resemblance to smocks worn by farmers in an earlier period. Smock mills differ from tower mills, which are usually cylindrical rather than hexagonal or octagonal, and built from brick or stone masonry instead of timber. The majority of smock mills are octagonal in plan, with a lesser number hexagonal in plan, such as Killick's Mill, Meopham. A very small number of smock mills were decagonal or dodecagonal in plan, an example of the latter being at Wicken, Cambridgeshire.

MECHANICS-Sails

Kuressaare (Arensburg) sai linnaõiguse
8. mail 1563 Saare-Lääne ja Kuramaa piiskop Magnuselt
EESTI 0.45 €
L. LÕHMUS 2013



Windmill in Kuremaa, Estonia

Common sails consist of a lattice framework on which a sailcloth is spread. The miller can adjust the amount of cloth spread according to the wind and the power needed. In medieval mills, the sailcloth was wound in and out of a ladder type arrangement of sails. Later mill sails had a lattice framework over which the sailcloth was spread, while in colder climates, the cloth was replaced by wooden slats, which were easier to handle in freezing conditions.The jib sail is commonly found in Mediterranean countries, and consists of a simple triangle of cloth wound round a spar.and/or tail wheel driving the stone nuts directly, instead of the spur gear arrangement. Additional gear wheels drive a sack hoist or other machinery. The machinery differs if the windmill is used for other applications than milling grain. A drainage mill uses another set of gear wheels on the bottom end of the upright shaft to drive a scoop wheel or Archimedes' screw. Sawmills use a crankshaft to provide a reciprocating motion to the saws. Windmills have been used to power many other industrial processes, including papermills, threshing mills, and to process oil seeds, wool, paints and stone products.

Water turbine In all cases, the mill needs to be stopped to adjust the sails. Inventions in Great Britain in the late eighteenth and nineteenth centuries led to sails that automatically adjust to the wind speed without the need for the miller to intervene, culminating in patent sails invented by William Cubitt in 1807. In these sails, the cloth is replaced by a mechanism of connected shutters.

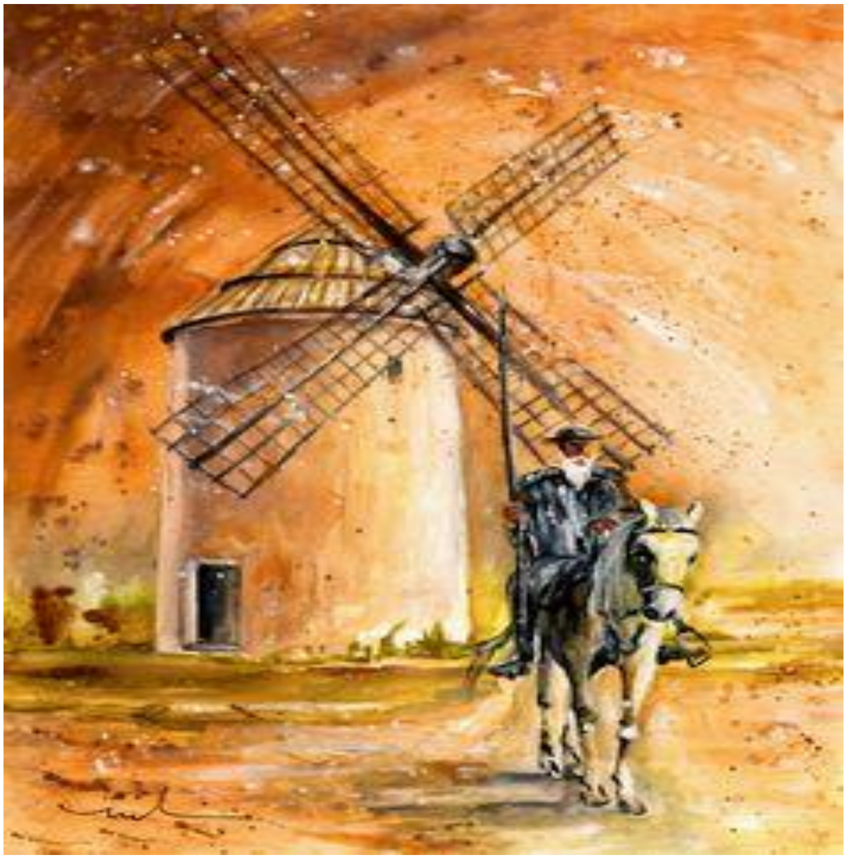
In France, Pierre-Théophile Berton invented a system consisting of longitudinal wooden slats connected by a mechanism that lets the miller open them while the mill is turning. In the twentieth century, increased knowledge of aerodynamics from the development of the airplane led to further improvements in efficiency by German engineer Bilau and several Dutch millwrights. The majority of windmills have four sails. Multiple-sailed mills, with five, six or eight sails, were built in Great Britain (especially in and around the counties of Lincolnshire and Yorkshire), Germany, and less commonly elsewhere. Earlier multiple-sailed mills are found in Spain, Portugal, Greece, parts of Romania, Bulgaria, and Russia.[26] A mill with an even number of sails has the advantage of being able to run with a damaged sail by removing both the damaged sail and the one opposite, which does not unbalance the mill.

De Valk ***windmill in mourning position following the death of*** *Queen Wilhelmina of the Netherlands* ***in 1962***

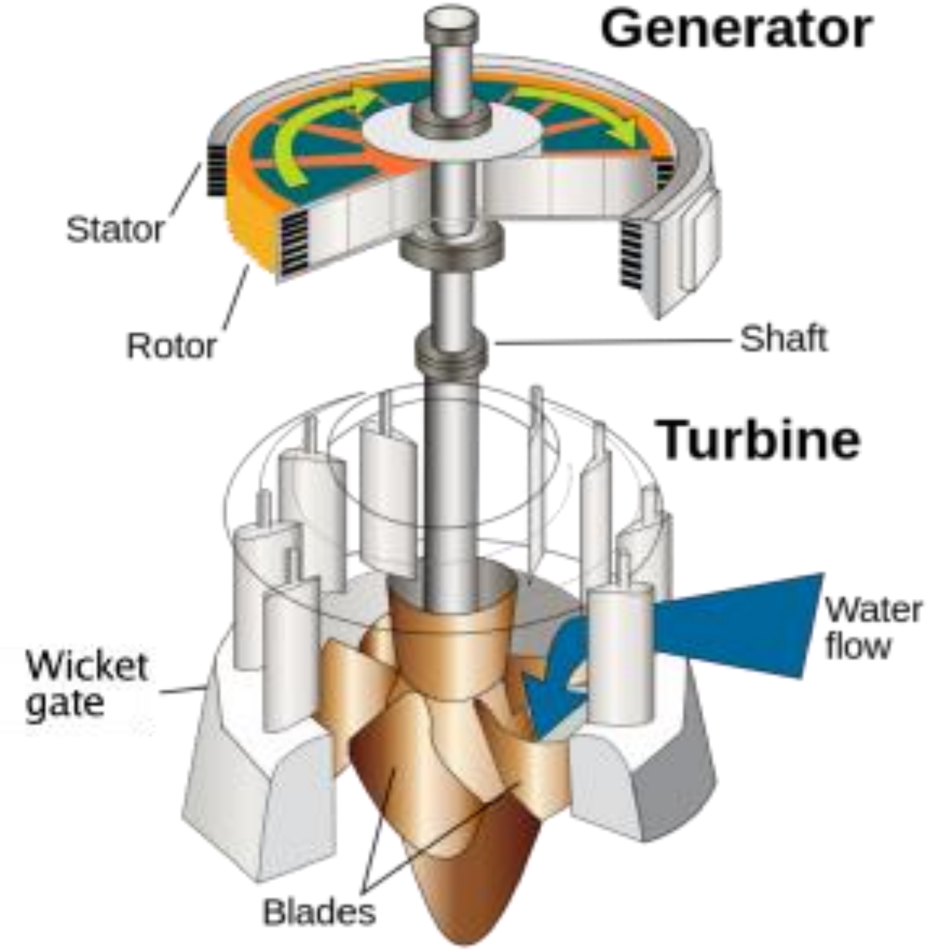
In the Netherlands the stationary position of the sails, i.e. when the mill is not working, has long been used to give signals. If the blades are stopped in a "+" sign (3-6-9-12 o'clock), the windmill is open for business. When the blades are stopped in an "X" configuration, the windmill is closed or not functional. A slight tilt of the sails (top blade at 1 o'clock) signals joy, such as the birth of a healthy baby. A tilt of the blades to 11-2-5-8 o'clock signals mourning, or warning. It was used to signal the local region during Nazi operations in World War II, such as searches for Jews. Across the Netherlands, windmills were placed in mourning position in honor of the Dutch victims of the 2014 Malaysian Airlines Flight 17 shootdown.

Machinery

Gears inside a windmill convey power from the rotary motion of the sails to a mechanical device. The sails are carried on the horizontal windshaft. Windshafts can be wholly made of wood, or wood with a cast iron poll end (where the sails are mounted) or entirely of cast iron. The brake wheel is fitted onto the windshaft between the front and rear bearing. It has the brake around the outside of the rim and teeth in the side of the rim which drive the horizontal gearwheel called wallower on the top end of the vertical upright shaft. In grist mills, the great spur wheel, lower down the upright shaft, drives one or more stone nuts on the shafts driving each millstone. Post mills sometimes have a head



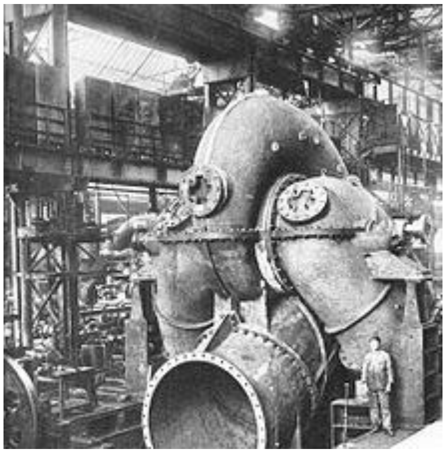
Kaplan turbine and electrical generator cut-away view.



The runner of the small water turbine

A water turbine is a rotary machine that converts kinetic energy and potential energy of water into mechanical work. A water turbine is a rotary machine that converts kinetic energy and potential energy of water into mechanical work.

Water turbines were developed in the 19th century and were widely used for industrial power prior to electrical grids. Now they are mostly used for electric power generation. Water turbines are mostly found in dams to generate electric power from water potential energy.



The construction of a Ganz water Turbo Generator in Budapest in 1886

Water wheels have been used for hundreds of years for industrial power. Their main shortcoming is size, which limits the flow rate and head that can be harnessed. The migration from water wheels to modern turbines took about one hundred years. Development occurred during the Industrial revolution, using scientific principles and methods. They also made extensive use of new materials and manufacturing methods developed at the time.

Swirl

The word turbine was introduced by the French engineer Claude Burdin in the early 19th century and is derived from the Greek word "τύρβη" for "whirling" or a "vortex". The main difference between early water turbines and water wheels is a swirl component of the water which passes energy to a spinning rotor. This additional component of motion allowed the turbine to be smaller than a water wheel of the same power. They could process more water by spinning faster and could harness much greater heads. (Later, impulse turbines were developed which didn't use swirl.)

History

Roman turbine mill at Chemtou, Tunisia. The tangential water inflow of the millrace made the submerged horizontal wheel in the shaft turn like a true turbine.[1]

A Francis turbine runner, rated at nearly one million hp (750 MW), being installed at the Grand Coulee Dam, United States.

A propeller-type runner rated 28,000 hp (21 MW)

The earliest known water turbines date to the Roman Empire. Two helix-turbine mill sites of almost identical design were found at Chemtou and Testour, modern-day Tunisia, dating to the late 3rd or early 4th century AD. The horizontal water wheel with angled blades was installed at the bottom of a water-filled, circular shaft. The water from the mill-race entered the pit tangentially, creating a swirling water column which made the fully submerged wheel act like a true turbine.[1]

Fausto Veranzio in his book *Machinae Novae* (1595) described a vertical axis mill with a rotor similar to that of a Francis turbine.

Johann Segner developed a reactive water turbine (Segner wheel) in the mid-18th century in Kingdom of Hungary. It had a horizontal axis and was a precursor to modern water turbines. It is a very simple machine that is still produced today for use in small hydro sites. Segner worked with Euler on some of the early mathematical theories of turbine design. In the 18th century, a Dr. Robert Barker invented a similar reaction hydraulic turbine that became popular as a lecture-hall demonstration.[3] The only known surviving example of this type of engine used in power production, dating from 1851, is found at Hacienda Buena Vista in Ponce, Puerto Rico.

In 1820, Jean-Victor Poncelet developed an inward-flow turbine.

In 1826, Benoît Fourneyron developed an outward-flow turbine. This was an efficient machine (~80%) that sent water through a runner with blades curved in one dimension. The stationary outlet also had curved guides.

In 1844, Uriah A. Boyden developed an outward flow turbine that improved on the performance of the Fourneyron turbine. Its runner shape was similar to that of a Francis turbine.

In 1849, James B. Francis improved the inward flow reaction turbine to over 90% efficiency. He also conducted sophisticated tests and developed engineering methods for water turbine design. The Francis turbine, named for him, is the first modern water turbine. It is still the most widely used water turbine in the world today. The Francis turbine is also called a radial flow turbine, since water flows from the outer circumference towards the centre of runner.

Inward flow water turbines have a better mechanical arrangement and all modern reaction water turbines are of this design. As the water swirls inward, it accelerates, and transfers energy to the runner. Water pressure decreases to atmospheric, or in some cases subatmospheric, as the water passes through the turbine blades and loses energy.

Around 1890, the modern fluid bearing was invented, now universally used to support heavy water turbine spindles. As of 2002, fluid bearings appear to have a mean time between failures of more than 1300 years.

Around 1913, Viktor Kaplan created the Kaplan turbine, a propeller-type machine. It was an evolution of the Francis turbine and revolutionized the ability to develop low-head hydro sites.

New concept

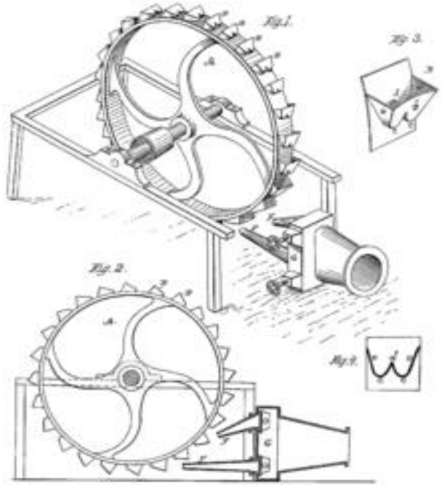


Figure from Pelton's original patent (October 1880)

All common water machines until the late 19th century (including water wheels) were basically reaction machines; water *pressure* head acted on the machine and produced work. A reaction turbine needs to fully contain the water during energy transfer.

In 1866, California millwright Samuel Knight invented a machine that took the impulse system to a new level. Inspired by the high pressure jet systems used in hydraulic mining in the gold fields, Knight developed a bucketed wheel which captured the energy of a free jet, which had converted a high head (hundreds of vertical feet in a pipe or penstock) of water to kinetic energy. This is called an impulse or tangential turbine. The water's velocity, roughly twice the velocity of the bucket periphery, does a U-turn in the bucket and drops out of the runner at low velocity.

In 1879, Lester Pelton, experimenting with a Knight Wheel, developed a Pelton wheel (double bucket design), which exhausted the water to the side, eliminating some energy loss of the Knight wheel which exhausted some water back against the center of the wheel. In about 1895, William Doble improved on Pelton's half-cylindrical bucket form with an elliptical bucket that included a cut in it to allow the jet a cleaner bucket entry. This is the modern form of the Pelton turbine which today achieves up to 92% efficiency. Pelton had been quite an effective promoter of his design and although Doble took over the Pelton company he did not change the name to Doble because it had brand name recognition.

Turgo and cross-flow turbines were later impulse designs.

Operational Theorey: Flowing water is directed on to the blades of a turbine runner, creating a force on the blades. Since the runner is spinning, the force acts through a distance (force acting through a distance is the definition of work). In this way, energy is transferred from the water flow to the turbine.

Water turbines are divided into two groups: reaction turbines and impulse turbines.

The precise shape of water turbine blades is a function of the supply pressure of water, and the type of impeller selected.

Reaction turbines

Reaction turbines are acted on by water, which changes pressure as it moves through the turbine and gives up its energy. They must be encased to contain the water pressure (or suction), or they must be fully submerged in the water flow.

Newton's third law describes the transfer of energy for reaction turbines.

Most water turbines in use are reaction turbines and are used in low (<30 m or 100 ft) and medium (30–300 m or 100–1,000 ft) head applications. In reaction turbine pressure drop occurs in both fixed and moving blades. It is largely used in dam and large power plants

Impulse turbines

Impulse turbines change the velocity of a water jet. The jet pushes on the turbine's curved blades which changes the direction of the flow. The resulting change in momentum (impulse) causes a force on the turbine blades. Since the turbine is spinning, the force acts through a distance (work) and the diverted water flow is left with diminished energy. An impulse turbine is one in which the pressure of the fluid flowing over the rotor blades is constant and all the work output is due to the change in kinetic energy of the fluid.

Prior to hitting the turbine blades, the water's pressure (potential energy) is converted to kinetic energy by a nozzle and focused on the turbine. No pressure change occurs at the turbine blades, and the turbine doesn't require a housing for operation.

Newton's second law describes the transfer of energy for impulse turbines.

Impulse turbines are often used in very high (>300m/1000 ft) head applications.

Power

The power available in a stream is;
where:

- power (J/s or watts)
- turbine efficiency
- density of fluid (kg/m^3)
- acceleration of gravity (9.81 m/s^2)

- head (m). For still water, this is the difference in height between the inlet and outlet surfaces. Moving water has an additional component added to account for the kinetic energy of the flow. The total head equals the *pressure head* plus *velocity head*.
- = flow rate (m³/s)

Pumped-storage hydroelectricity

Some water turbines are designed for pumped-storage hydroelectricity. They can reverse flow and operate as a pump to fill a high reservoir during off-peak electrical hours, and then revert to a water turbine for power generation during peak electrical demand. This type of turbine is usually a Deriaz or Francis turbine in design.

This type of system is used in El Hierro, one of the Canary Islands: "When wind production exceeds demand, excess energy will pump water from a lower reservoir at the bottom of a volcanic cone to an upper reservoir at the top of the volcano 700 meters above sea level. The lower reservoir stores 150,000 cubic meters of water. The stored water acts as a battery. The maximum storage capacity is 270 MWh. When demand rises and there is not enough wind power, the water will be released to four hydroelectric turbines with a total capacity of 11 MW."

Efficiency

Large modern water turbines operate at mechanical efficiencies greater than 90%.

Water Turbine Types

Various types of water turbine runners. From left to right: Pelton wheel, two types of Francis turbine and Kaplan turbine.

Reaction turbines

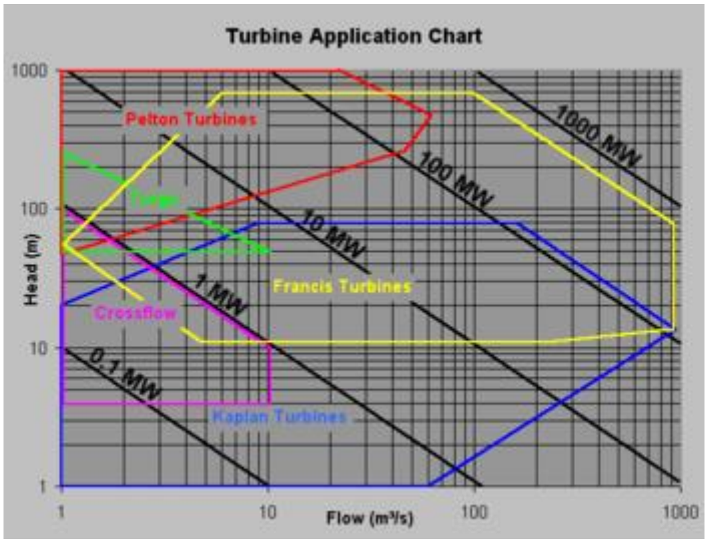
- VLH turbine
- Francis turbine
- Kaplan turbine

- Tyson turbine
- Deriaz turbine
- Gorlov helical turbine

Impulse turbine

- Water wheel
- Pelton wheel
- Turgo turbine
- Cross-flow turbine (also known as the Bánki-Michell turbine, or Ossberger turbine)
- Jonval turbine
- Reverse overshot water-wheel
- Screw turbine
- Barkh Turbine

Design and application



Turbine selection is based on the available water head, and less so on the available flow rate. In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites. Kaplan turbines with adjustable blade pitch are well-adapted to wide ranges of flow or head conditions, since their peak efficiency can be achieved over a wide range of flow conditions.

Small turbines (mostly under 10 MW) may have horizontal shafts, and even fairly large bulb-type turbines up to 100 MW or so may be horizontal. Very large Francis and Kaplan machines usually have vertical shafts because this makes best use of the available head, and makes installation of a generator more economical. Pelton wheels may be either vertical or horizontal shaft machines because the size of the machine is so much less than the available head. Some impulse turbines use multiple jets per runner to balance shaft thrust. This also allows for the use of a smaller turbine runner, which can decrease costs and mechanical losses.

Typical range of heads

- Water wheel0.2 < H < 4 (H = head in m)
- Screw turbine1 < H < 10
- VLH turbine1.5 < H < 4.5
- Kaplan turbine2 < H < 70
- Francis turbine10 < H < 300[10]
- Pelton wheel80 < H < 1600
- Turgo turbine 50 < H < 250

Specific speed

The specific speed of a turbine characterizes the turbine's shape in a way that is not related to its size. This allows a new turbine design to be scaled from an existing design of known performance. The specific speed is also the main criteria for matching a specific hydro site with the correct turbine type. The specific speed is the speed with which the turbine turns for a particular discharge Q, with unit head and thereby is able to produce unit power.

Affinity laws

Affinity laws allow the output of a turbine to be predicted based on model tests. A miniature replica of a proposed design, about one foot (0.3 m) in diameter, can be tested and the laboratory measurements applied to the final application with high confidence. Affinity laws are derived by requiring similitude between the test model and the application.

Flow through the turbine is controlled either by a large valve or by wicket gates arranged around the outside of the turbine runner. Differential head and flow can be plotted for a number of different values of gate opening, producing a hill diagram used to show the efficiency of the turbine at varying conditions.

Runaway speed

The **runaway speed** of a water turbine is its speed at full flow, and no shaft load. The turbine will be designed to survive the mechanical forces of this speed. The manufacturer will supply the runaway speed rating.

Control Systems: Different designs of governors have been used since the mid-18th century to control the speeds of the water turbines. A variety of flyball systems, or first-generation governors, were used during the first 100 years of water turbine speed controls. In early flyball systems, the flyball component countered by a spring acted directly to the valve of the turbine or the wicket gate to control the amount of water that enters the turbines. Newer systems with mechanical governors started around 1880. An early mechanical governor is a servomechanism that comprises a series of gears that use the turbine's speed to drive the flyball and turbine's power to drive the control mechanism. The mechanical governors were continued to be enhanced in power amplification through the use of gears and the dynamic behavior. By 1930, the mechanical governors had many parameters that could be set on the feedback system for precise controls. In the later part of the twentieth century, electronic governors and digital systems started to replace the mechanical governors. In the electronic governors, also known as second-generation governors, the flyball was replaced by rotational speed sensor but the controls were still done through analog systems. In the modern systems, also known as third-generation governors, the controls are performed digitally by algorithms that are programmed to the computer of the governor.

Turbine Blades: Given that the turbine blades in a water turbine are constantly exposed to water and dynamic forces, they need to have high corrosion resistance and strength. The most common material used in overlays on carbon steel runners in water turbines are austenitic steel alloys that have 17% to 20% chromium to increase stability of the film which improves aqueous corrosion resistance. The chromium content in these steel alloys exceed the minimum of 12% chromium required to exhibit some atmospheric corrosion resistance. Having a higher chromium concentration in the steel alloys allows for a much longer lifespan of the turbine blades. Currently, the blades are made of martensitic stainless steels which have high strength compared to austenitic stainless steels by a factor of 2. Besides corrosion resistance and strength as the criteria for material selection, weld-ability and density of the turbine blade. Greater weld-ability allows for easier repair of the turbine blades. This also allows for higher weld quality which results in a better repair. Selecting a material with low density is important to achieve higher efficiency because the lighter blades rotate more easily. The most common material used in Kaplan Turbine blades are stainless steel alloys (SS). The martensitic stainless steel alloys have high strength, thinner sections than standard carbon steel, and reduced mass that enhances the hydrodynamic flow conditions and efficiency of the water turbine.[12] The SS(13Cr-4Ni) has been shown to have improved erosion resistance at all angles of attack through the process of laser hardening.[13] It is important to minimize erosion in order to maintain high efficiencies because erosion negatively impacts the hydraulic profile of the blades which reduces the relative ease to rotate.

Maintenance: Turbines are designed to run for decades with very little maintenance of the main elements; overhaul intervals are on the order of several years. Maintenance of the runners and parts exposed to water include removal, inspection, and repair of worn parts.

Normal wear and tear includes pitting corrosion from cavitation, fatigue cracking, and abrasion from suspended solids in the water. Steel elements are repaired by welding, usually with stainless steel rods. Damaged areas are cut or ground out, then welded back up to their original or an improved profile. Old turbine runners may have a significant amount of stainless steel added this way by the end of their lifetime. Elaborate welding procedures may be used to achieve the highest quality repairs.

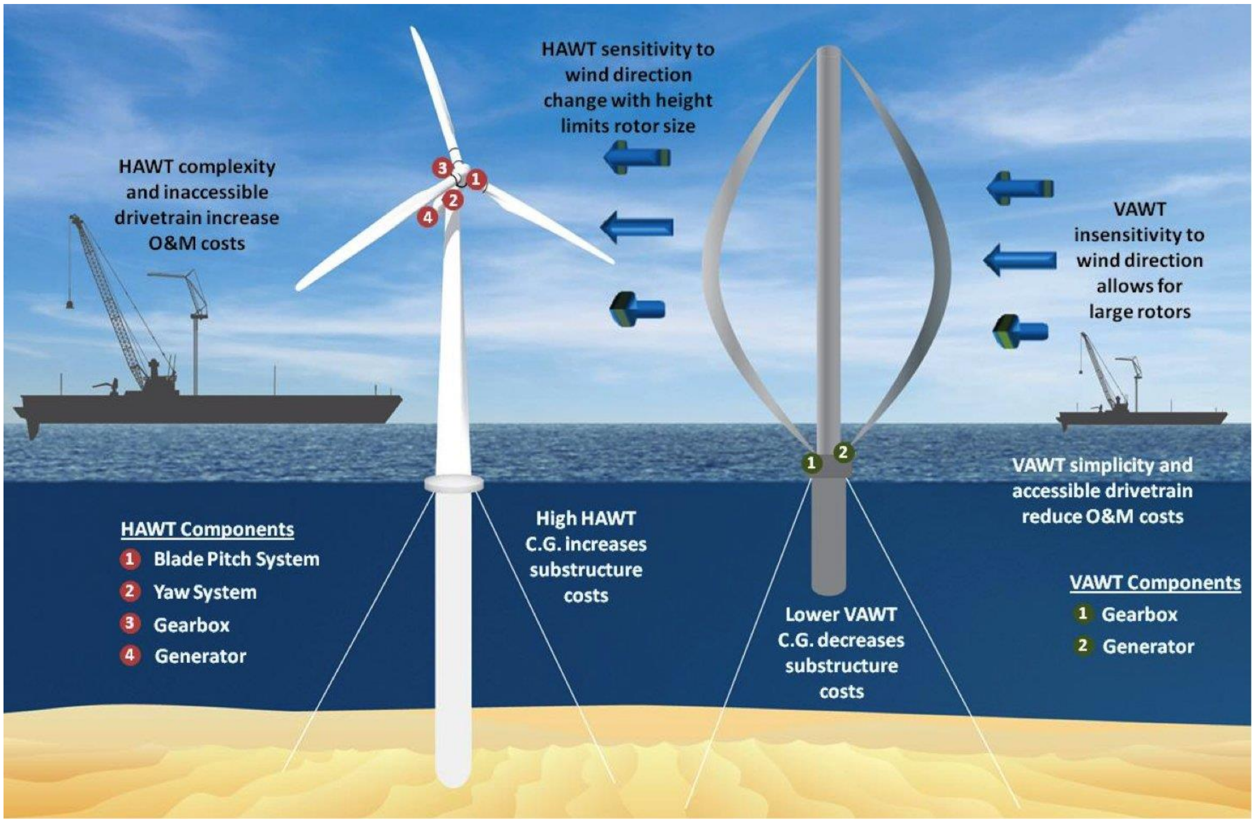
Other elements requiring inspection and repair during overhauls include bearings, packing box and shaft sleeves, servomotors, cooling systems for the bearings and generator coils, seal rings, wicket gate linkage elements and all surfaces.

Eco Friendly: Water turbines are generally considered a clean power producer, as the turbine causes essentially no change to the water. They use a renewable energy source and are designed to operate for decades. They produce significant amounts of the world's electrical supply.

Historically there have also been negative consequences, mostly associated with the dams normally required for power production. Dams alter the natural ecology of rivers, potentially killing fish, stopping migrations, and disrupting peoples' livelihoods. For example, Native

American tribes in the Pacific Northwest had livelihoods built around salmon fishing, but aggressive dam-building destroyed their way of life. Dams also cause less obvious, but potentially serious consequences, including increased evaporation of water (especially in arid regions), buildup of silt behind the dam, and changes to water temperature and flow patterns. In the United States, it is now illegal to block the migration of fish, for example the white sturgeon in North America, so fish ladders must be provided by dam builders.

HOW A WIND TURBINE WORKS[2]


HAWT sensitivity to wind direction change with height limits rotor size
HAWT complexity and inaccessible drivetrain increase O&M costs
3
1
2
4
VAWT insensitivity to wind direction allows for large rotors
1
2
VAWT simplicity and accessible drivetrain reduce O&M costs
HAWT Components
1 Blade Pitch System
2 Yaw System
3 Gearbox
4 Generator
High HAWT C.G. increases substructure costs
Lower VAWT C.G. decreases substructure costs
VAWT Components
1 Gearbox
2 Generator

Wind power involves converting wind energy into electricity by using wind turbines. A wind turbine usually has three propellers-like blades called *rotors.* The rotor is attached to a tall tower. On average, wind towers in residential settings are about 20m high. The reason why the tower is so tall is that winds are stronger higher from the ground and there’s less of a buffeting effect.

Vertical and horizontal axis turbines used for residential electricity generation

Wind comes from atmospheric changes: changes in temperature and pressure makes the air move around the surface of the earth. All of which is triggered by the sun. So in a way, wind energy is another form of solar power.

A wind turbine captures the wind, which then produces a renewable energy source. The wind makes the rotor spin; as the rotor spins, the movement of the blades drives a generator that creates energy. The motion of the blades turning is *kinetic energy*. It is this power that we convert into electricity.

How is electricity made from turbines?

Wind power converts into electricity by magnets moving past stationary coils of wire known as the *stator*. As the magnets pass the stator, AC electricity production occurs. It is then converted into DC electricity. This can charge batteries which store the electrical energy or can feed into a grid-interactive inverter for feeding power into the electricity grid.

The advantages of wind energy

Wind power is a clean energy source that we can rely on for the long-term future. A wind turbine creates reliable, cost-effective, pollution-free energy. It is affordable, clean and sustainable. One wind turbine can be sufficient to generate energy for a household.

Because wind is a source of energy which is non-polluting and renewable, the turbines create power without using fossil fuels. That is, without producing greenhouse gases or radioactive or toxic waste.

What is the cost of wind energy?

Today, this renewable energy source is one of the most cost-effective options to choose from. In fact, it’s the cheapest of all large-scale alternatives on the market. In 2018 alone, Australia’s wind farms produced approximated 33.5 per cent of the nation’s total clean energy supply, creating a further 71.5 per cent of the country’s electricity.

Because of this accessibility, the cost of wind energy continues to be a reliable and stable option for Australia to lean on. In a nutshell, an individual turbine costs approximately $7,000 to $20,000 to be installed, depending on the specific type.

Turbine installation

You can install wind turbines on properties, on boats, or caravans. Whether it is viable depends entirely on the number of wind resources available in your area. The first thing you need to do is to find out the average speed in your area. While using freely available data gives an indication, the most reliable method is a reading taken at your site.

The average wind speed needs to be above 5m/s (18km per hour) to make installing a wind turbine worthwhile. Ideal locations for wind turbines are:

- in the country,
- on farms, or
- on the coast

Basically, anywhere away from built-up areas. The more buildings around the installation, the less wind there is. Setting up a wind turbine is a big job that takes time. It can be a very cost-effective way of creating power as long as the average wind speed is high enough.

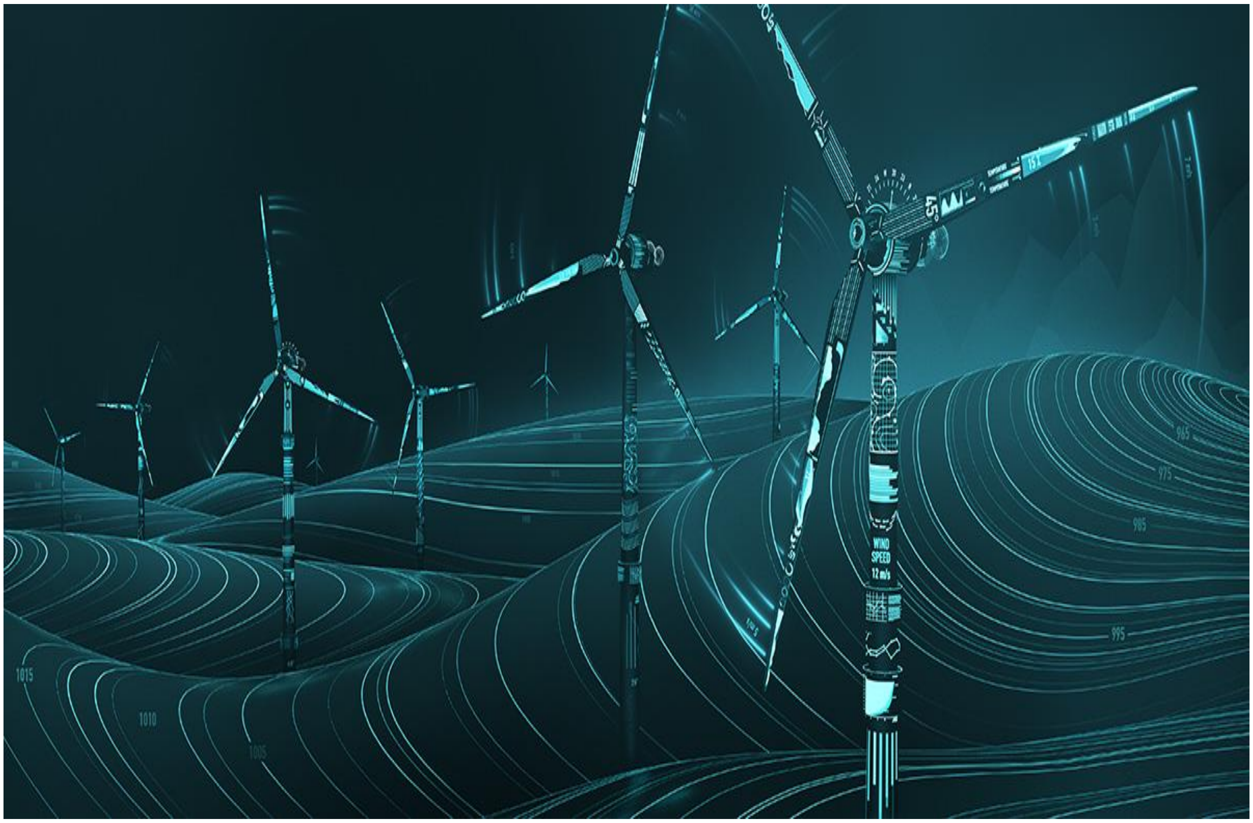
Typically standing at least 80 meters (262 feet) tall, tubular steel towers support a hub with three attached blades and a “nacelle,” which houses the shaft, gearbox, generator, and controls. Wind measurements are collected, which direct the turbine to rotate and face the strongest wind, and the angle or "pitch" of its blades is optimized to capture energy.

Global
Wind Turbine
Market
OPPORTUNITIES AND FORECASTS, 2017-2023
Wind Turbine Market is expected to reach $134,600 million by 2023.
Growing at a CAGR of 7.2% (2017-2023)
©Allied Market Research

A typical modern turbine will start to generate electricity when wind speeds reach six to nine miles per hour (mph), known as the cut-in speed. Turbines will shut down if the wind is blowing too hard (roughly 55 miles an hour) to prevent equipment damage.

Over the course of a year, modern turbines can generate usable amounts of electricity over 90 percent of the time. For example, if the wind at a turbine reaches the cut-in speed of six to nine mph, the turbine will start generating electricity. As wind speeds increase so does electricity production.

Another common measure of wind energy production is called capacity factor. This measures the amount of electricity a wind turbine produces in a given time period (typically a year) relative to its maximum potential.



For example, suppose the maximum theoretical output of a two megawatt wind turbine in a year is 17,520 megawatt-hours (two times 8,760 hours, the number of hours in a year). However, the turbine may only produce 7,884 megawatt-hours over the course of the year because the wind wasn’t always blowing hard enough to generate the maximum amount of electricity the turbine was capable of producing. In this case, the turbine has a 45 percent (7,884 divided by 17,520) capacity factor. Remember—this does not mean the turbine only generated electricity 45 percent of the time. Modern wind farms often have capacity factors greater than 40 percent, which is close to some types of coal or natural gas power plants.

Windmills vs. Wind Turbines

Sometimes people use the terms “windmill” and “wind turbine” interchangeably, but there are important differences. People have been using windmills for centuries to grind grain, pump water, and do other work. Windmills generate mechanical energy, but they do not generate electricity. In contrast, modern wind turbines are highly evolved machines with more than 8,000 parts that harness wind's kinetic energy and convert it into electricity.

What is a wind farm?

Oftentimes a large number of wind turbines are built close together, which is referred to as a wind project or wind farm. A wind farm functions as a single power plant and sends electricity to the grid.

How wind energy gets to you

The turbines in a wind farm are connected so the electricity they generate can travel from the wind farm to the power grid. Once wind energy is on the main power grid, electric utilities or power operators will send the electricity to where people need it.

Smaller transmission lines, called distribution lines, collect electricity generated at the wind project and transport it to larger "network" transmission lines, where the electricity can travel across long distances to the locations where it is needed. Finally, smaller distribution lines deliver electricity directly to your town, home or business.

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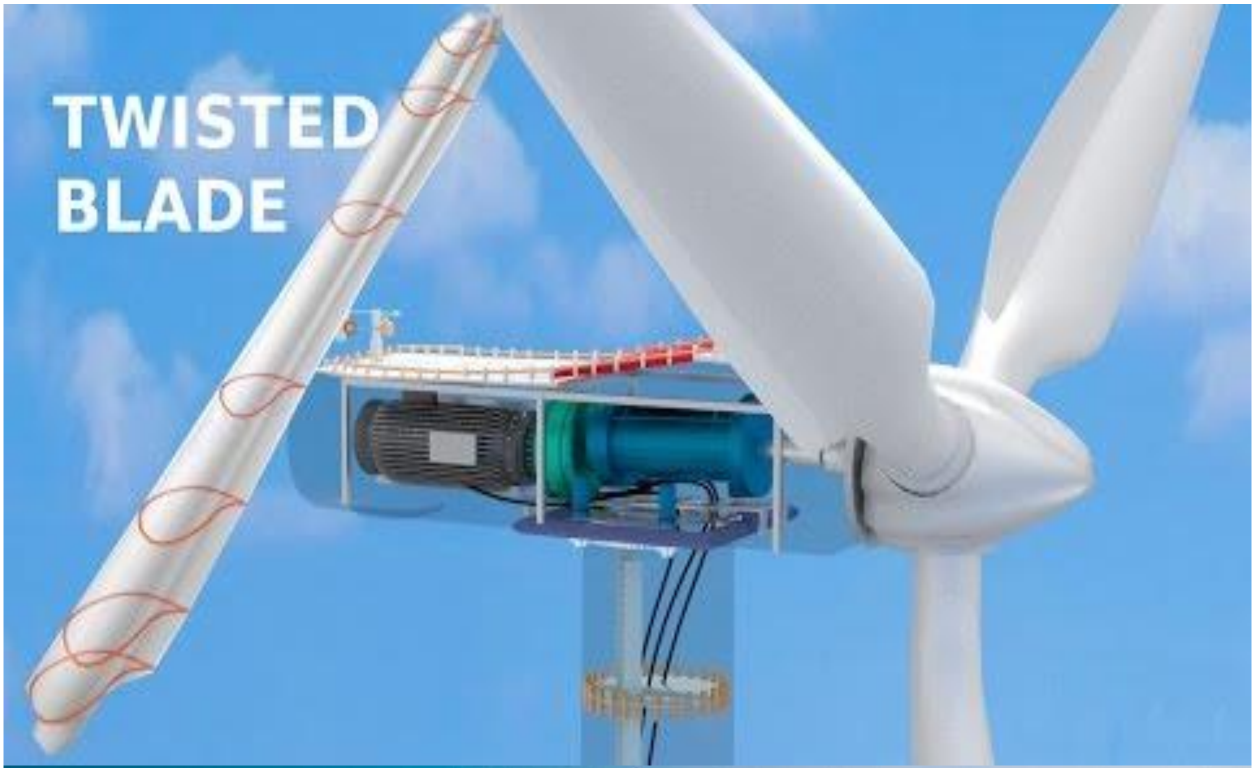
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REFERENCES

1.*Heaven's Breath: A Natural History of the Wind,Lyall Watson,2019*

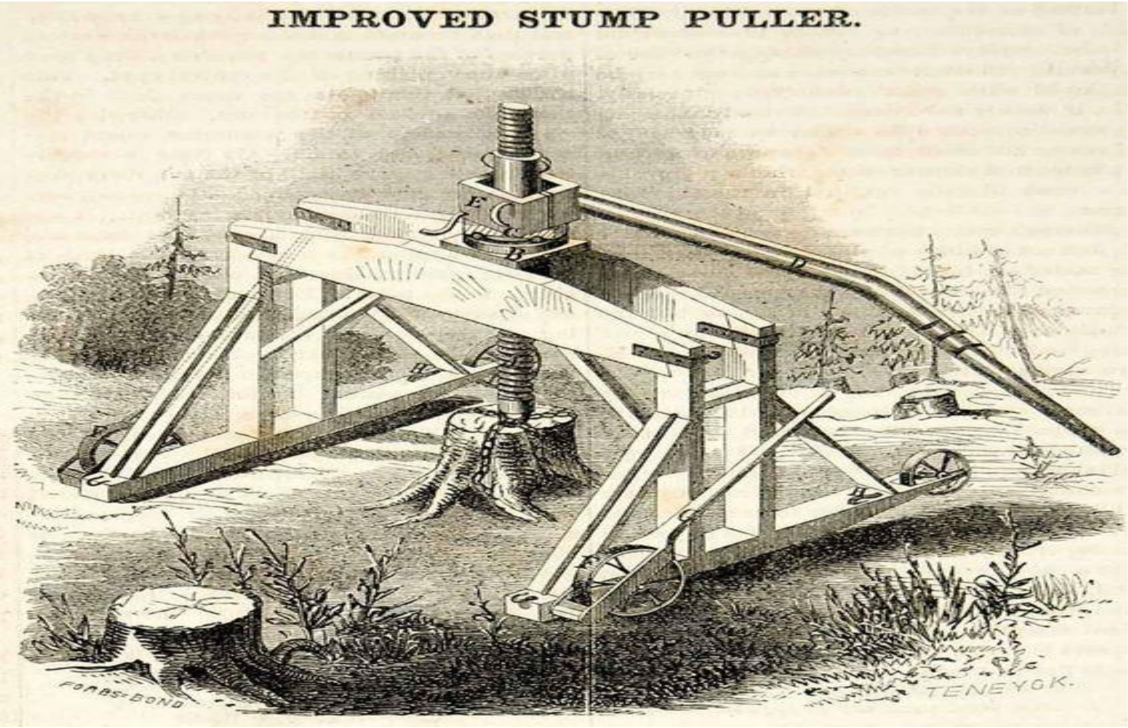
2. *https://www.energymatters.com.au/components/wind-energy/*

CHAPTER VIII

Lighthouses: Then and Now

INTRODUCTION Emitting powerful light that pierces fog and darkness, lighthouses are vital to maritime navigation. They serve as beacons and guides, ensuring safe passage for shipping. The need of lighted beacons to guide water craft along the coasts must have suggested itself to mankind as soon as there was much venturing upon the water. The lofty Pharos of Alexandria, near the mouth of the Nile, was completed under Ptolemy II, about 280 B.C. In height and fame it has never been surpassed by any other lighthouse and is considered one of the seven wonders of the world. Many of the world's early lighthouses may have looked like this Roman lighthouse that still stands in Dover, England.

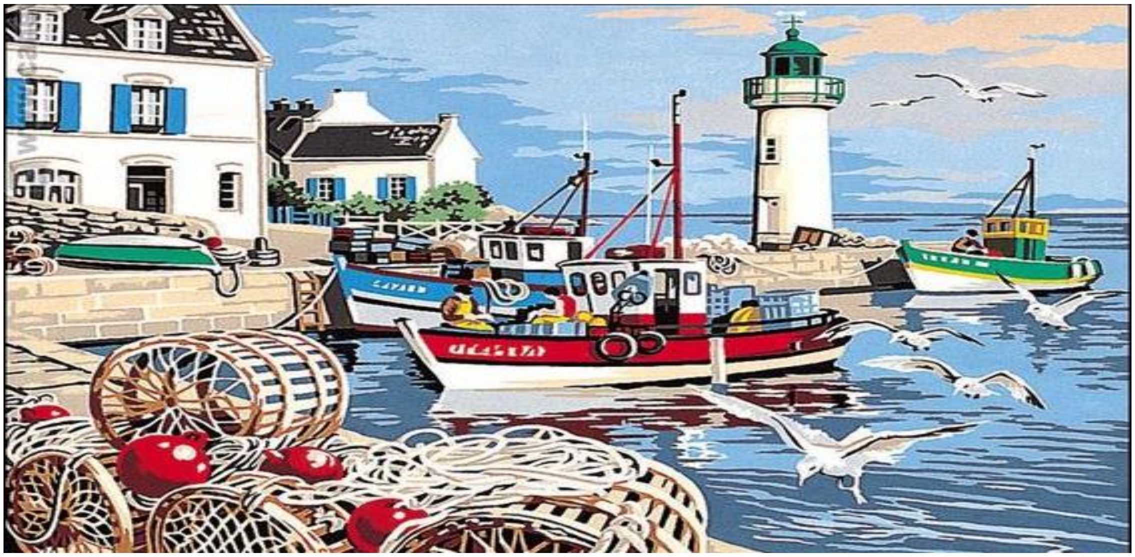
The number of lights in the world, however, was relatively small when the first lighthouse in the North American colonies was established on Great Brewster Island at Boston in 1716.



One of the most frequently asked questions is how many lighthouses have been built. This is not a question that can be easily answered because almost every lighthouse has been rebuilt at one time or another. How much change has to take place before the old structure loses its identity and becomes a new one? For example, the Point Bonita light was built on a promenade too high above the sea to be effective. A shorter tower, the one pictured, was erected at a lower site and the lantern house--the top third of the structure--was removed from the original tower and placed on top of the new structure. Is this one or two lighthouses? Another lighthouse which clouds the count is Matinicus Rock light. The two towers which connected to the keepers quarters were capped and new towers, which were also attached to the keepers quarters were built. How many lights is this--one, two, or four? A number of sites had two unconnected towers and one even had three.

Nearly 1,500 lighthouse sites have existed in the United States at one time or another. The evolution of lighthouses has taken centuries and is profoundly influenced by the development of technology. Lighthouses as you know are very personal. They come in many shapes and sizes and everyone has his own definition and these vary sufficiently. When one thinks of lighthouses, the average person conjures up an image of a tall white tower on a point of land. Actually, lighthouses in this country were built in many shapes, sizes, and heights including cylindrical, conical, square, octagonal, and even triangular shaped, with towers that stand as high as 208 feet. Politics, special needs, cost, location, geography at the site, and available technology at the time of construction also influenced lighthouse design.Today, one need only review the literature to discover that most lighthouse books approach the subject on a regional basis.

Few lighthouse books, because of their regional approach, however, have a need to address trends in lighthouse construction. Permit me to offer a technological approach to the history of lighthouses.



Over 200 years of lighting the way

The 200th anniversary of the creation of the Lighthouse Service was celebrated in 1989. It as created in the ninth law enacted by the First Congress. That law required the federal government to assume responsibility for the nation's lighthouses. The Lighthouse Service became part of the Coast Guard in 1939.

The care of lighthouses falls under the Short-Range Aids to Navigation Program, one of four programs administered by the Office of Navigation. Aids to navigation are external references that help mariners determine the position of their vessel and choose a safe course. Short-range aids include buoys, beacons, lights, lighthouses, sound signals and ranges. Today, expensive and environmentally-hazardous batteries are being replaced by solar power and automated lighthouses.

The Office of Navigation

The Office of Navigation runs four programs with worldwide scope. This includes more than 96,000 federal and private aids to navigation. More than 4,000 people work in the navigation program. They operate a fleet of 80 cutters, hundreds of small boats, a global network of Loran-C and OMEGA radio-navigation stations and seven Vessel Traffic Services (VTS). More than 20 percent of the Coast Guard's budget is devoted to navigation programs.

The Radio-navigation Division, G-NRN, manages the Radio-navigation Program. This program includes Loran-C, OMEGA and a coastal radio-beacon system. The Loran-C system consists of 38 Coast Guard or host-nation staffed transmitting stations that provide coverage of the continental U.S., parts of the North Pacific Ocean, North Atlantic Ocean and Mediterranean Sea. The coverage meets Department of Defense requirements.

The Coast Guard also coordinates the operation of the OMEGA radio-navigation system. This system of eight stations located around the globe provides world-wide radio navigation coverage, but with less accuracy than Loran-C. Two OMEGA stations in North Dakota and Hawaii are Coast Guard staffed. Radio-beacons provide a positioning-fixing or homing capability in coastal and Great Lakes waters. There are more than 200 radio-beacon transmitters.

The Waterways Management Program, WWM, is a relative newcomer. It was added to the Navigation Systems Safe Division, G-NSS, in 1986. The program oversees several waterways management services including traffic separation schemes, regulated anchorage areas, and the international and Inland Navigational Rules. It is also the program manager for Vessel Traffic Services.

The fourth program is Bridge Administration. It deals with the permitting of bridges over navigable waters, the alteration of obstructive bridges and the regulation of drawbridges. The program is part of the Bridge Administration Division. It became a Coast Guard responsibility in 1967 when it was transferred from the Army Corps of Engineers. A project to return this program to the Corps is currently underway to lessen the regulatory burden on the public. Because of several environmental laws passed since 1967, the public must deal with both the Coast Guard and the Corps of Engineers in many bridge matters. A return to the Corps will lessen the bureaucratic delays for the public regarding bridge concerns.

The evolution of the lighthouse tower

Lighthouses come in many shapes and sizes. This evolution has taken centuries and was influenced by technological change. Twelve lighthouses were built in the United States before the Constitution transferred lighthouse control from the states to the federal government. No two were constructed from the same set of plans and all were built from local materials. Therefore, it is no surprise that no two were alike. Examination of the one which remains one which remains, Sandy Hook, New Jersey, and the evidence of those which have not survived, reveals that these did share some common features.

Painting by Anita Malfatti

These early lighthouses were constructed of wood or stone. Those built of wood eventually fell victim to fire. The stone towers were built simply by piling one stone on top of another. These were held together by mortar. Since the walls contained no additional support, such as reinforcing rods, they had to be tapered as they rose. This enabled the base to support the ever-increasing weight prevented the tower from becoming unstable. Therefore, the higher they wished to build the light, the thicker the tower had to be at the base.

Given the flat nature of East Coast geography, where all pre-federal lights were built, there was a need to build a lighthouse as tall as possible. Since colonial lights peaked at about 90 feet, we may assume that this was the maximum practical high for a tower built during this era. It is surprising how little we know about lighthouses of this era. We have almost no construction details. We do have the Sandy Hook tower to study, but there are still many unanswered questions.

Lighthouses built between 1789 and 1820 deserve close attention. In 1789 the federal government took over responsibility from the states and in 1820, the Fifth Auditor of the Treasury became responsible for lighthouses. At first, President George Washington took an active interest in lighthouses. It was not too long before the President had to delegate this responsibility. First, the responsibility passed to the Commissioner of the Revenue and then it went to the Secretary of the Treasury. For quite some time, Albert Gallatin, the Secretary from 1801 until 1814, played an active role in lighthouse administration. Hardly a year went by when one or two new lighthouses were not appropriated.

During the later days of this era, cut stones were used for the first time. This permitted the construction of taller and stronger towers because the weight could be more evenly distributed. Of the first forty towers constructed, only a few survive today. These include the abandoned tower at Cape Henry, Virginia; Portland Head, Maine; and Georgetown Harbor, South Carolina. Most of the remaining lights built during the 1789-1820 era were no longer standing during the U.S. Civil War

A villain has emerged from the Camelot-like history of the early days of lighthouse construction, the Fifth Auditor of the Treasury. From 1820 through 1852, he was responsible for lighthouse administration. Having become too large to remain a direct responsibility of the Secretary, it was assigned to this subordinate. The Fifth Auditor of the Treasury was a financial zealot who proudly returned funds appropriated for the construction and repair of lighthouses to the Treasury unspent. He was a lighthouse novice when assigned the task and did little to improve his knowledge of lighthouse technology during his 32-year tenure. This period, which began in 1820, might well be labeled the era of "the lowest bidder." The lighthouses built during this period were inferior structures constantly in need of replacement. Furthermore, the lighting system used was grossly inferior to, but far less expensive than, those employed in Europe.

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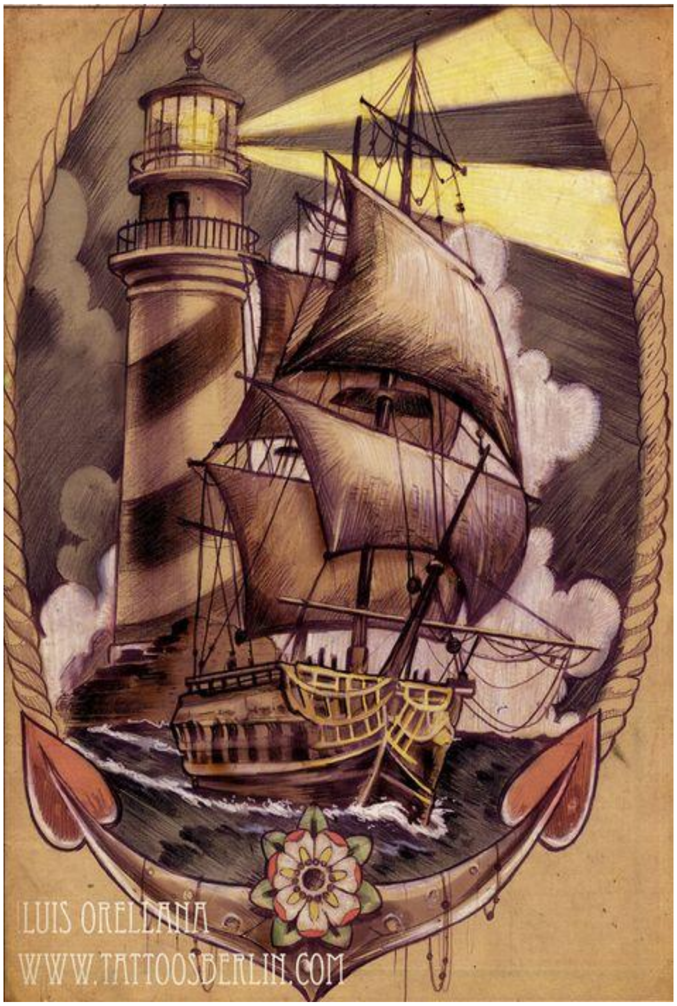
Not surprisingly, there are few examples of the Fifth Auditor lighthouses which have survived today. The evolution of the Matinicus Rock Light, however, is a good example of the fate of most constructed during the tenure of the Fifth Auditor. Three twin lighthouses were constructed at this site, the first in 1827, the second in 1848, and the third ten years later. The first two sets of towers were far too short and too close together. Adding to the Fifth Auditor's problems was the United States' addition of territories where the massive stone tower, had little value. For example, of the 40 or so brick towers built in the South, at least 25 either blew over or sank into the soft ground. In 1852, a special committee, appointed by Congress, conducted an investigation into the lighthouse system and concluded that it was grossly inadequate. A new era in American lighthouse construction was ushered in and the next few decades were the most dynamic period in American lighthouse construction. Although more attention has been given to technology's influence upon lighthouse construction during this period, the administrative change from the Fifth Auditor to the newly-created Lighthouse Board was more influential. The advances in technology had already taken place, they only needed to be applied to lighthouse construction.



The wave-swept lighthouse probably conforms to our mental image of a classical lighthouse more than any other two. The three most famous lights are Minots Ledge, Massachusetts; St. George's Reef, California; and Mile Rock, California. The first of these is probably the greatest engineering achievement of lighthouse construction given the difficulty of the task and the technology available.

The first attempt to put a lighthouse on Minots Ledge was during the closing days of the Fifth Auditor. This iron tower on stilts was destroyed by a storm a little over one year after completion. The legs held secure to the ledge in which they had been embedded; but they broke off. The second Minots Ledge structure was completed in 1860. A good part of its foundation is underwater. Work on preparing the ledge on which it sits took 3 years before the first course of stones were laid. The granite blocks are dove-tailed together and bonded vertically by bolts. The first 40 feet of the tower is solid stone. This tower is 97 feet tall and has been topped by a wave at least twice.

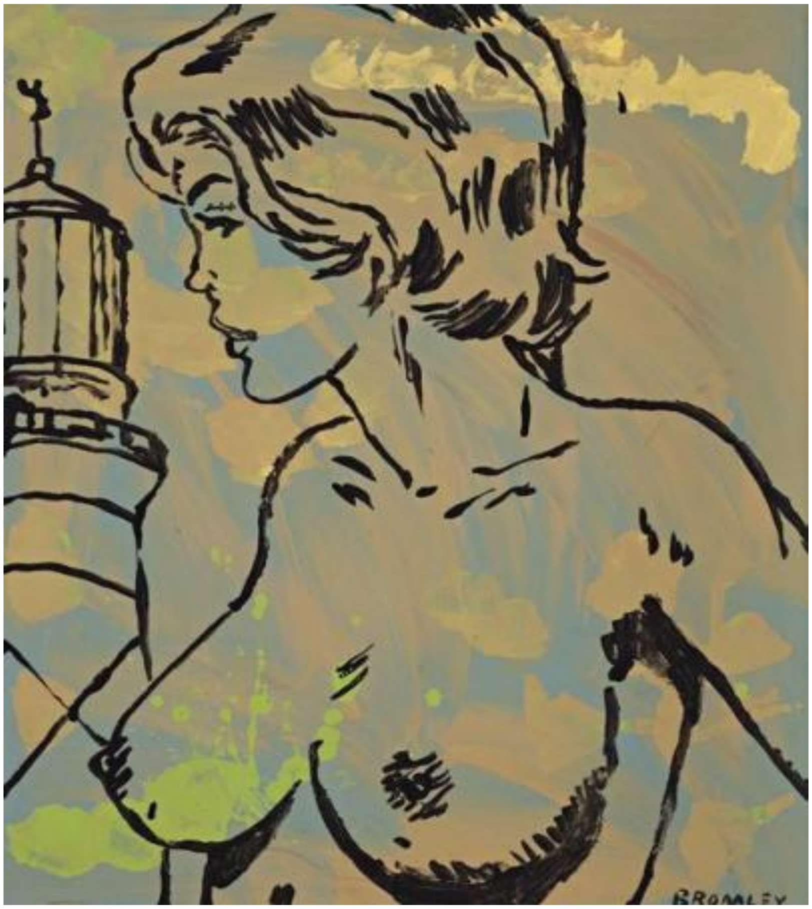
The protected, screw-pile lighthouse was introduced into the United States in 1850 during the closing days of the Fifth Auditor's reign. A protected, screw-pile lighthouse was typically a lightweight, wooden tower on iron stilts, the legs of which are tipped with cork-screw-like flanges. These legs are turned into the soft ground of protected waters, such as bays and sounds. This new type of lighthouse was dependent upon the development of wrought-iron columns for the legs and cast-iron for the screw-like flanges. This technology permitted the construction of lighthouses on sites too soft to support the weight of a heavy tower. The first screw-pile lighthouse had been built in England. This technology was introduced in America at Brandywine Shoals in the Delaware Bay in 1850. Within a few decades, perhaps as many as 100 protected screw-pile lighthouses were built throughout the United States, principally in the Carolina sounds and Chesapeake Bay. But they could also be found in the Gulf of Mexico and one was even built in the Great Lakes at Maumee Bay, but survived only a short time. This type of structure was particularly suited to slow moving, shallow water which was not subject to freezing. The principal enemies of this type of structure were fast-flowing water, ice, and fire. The screw-pile lighthouse design for exposed sites evolved two years after its less complex cousin, the type built for protected waters.

The exposed, screw-pile lighthouse was designed for and used in the Florida coral reefs. This structure varied in two important ways from the style designed for the protected bays and sounds. First, the lighthouse structure was a tall, skeleton iron tower and not a squat wooden structure. The screw-pile lighthouse in the bays and sounds did not need to project their lights more than a few miles so the height of the lens was not a major concern. But this was not for the Florida reef lights. These structures were to be major coastal lighthouses with first order lenses weighing a number of tons. Therefore, they had to be tall structures. The second major difference was in the screw flange. Large, iron-foot plates were added above the screw tip in order to diffuse the pressure caused the weight of the tower. Six screw-pile lighthouses for exposed sites were constructed in the Florida reefs, three before the Civil War and three afterward. Also, one light was built in the Gulf of Mexico at Ship Shoal, Louisiana, in 1858. Those built before the war are much more simple in appearance than those built two decades later.

The new Lighthouse Board of 1852 began the construction of brick towers of increasing height. By 1859 nine brick towers over 160 feet had been built. Six more were constructed after the Civil War. These towers are conical shape, except for Cape Romain, South Carolina, which is six-sided. None of the towers which they replaced topped 100 feet. One would suspect that some engineering or technological breakthrough had occurred in the 1850s which allowed over a 60-foot increase in the height of a coastal tower. This does not seem to be the case. Apparently, the walls of these towers are solid brick without reinforcements. This construction technique had existed long before the 1850s. There are a number of possible answers as to why the towers grew in the 1850s. The Fresnel lens was replacing the much less efficient reflector system; the new Lighthouse Board was willing to spend more on the construction of towers than the Fifth Auditor; and advancements in the science of mathematics allowed engineers to more accurately calculate stress factors. All but one of the 15 towers remain standing, although erosion makes the fate of a number of the others precarious. All 15 towers were built along the Atlantic Coast, as far north as Fire Island, New York, and as far south to Dry Tortugas, Florida The tallest of these, Cape

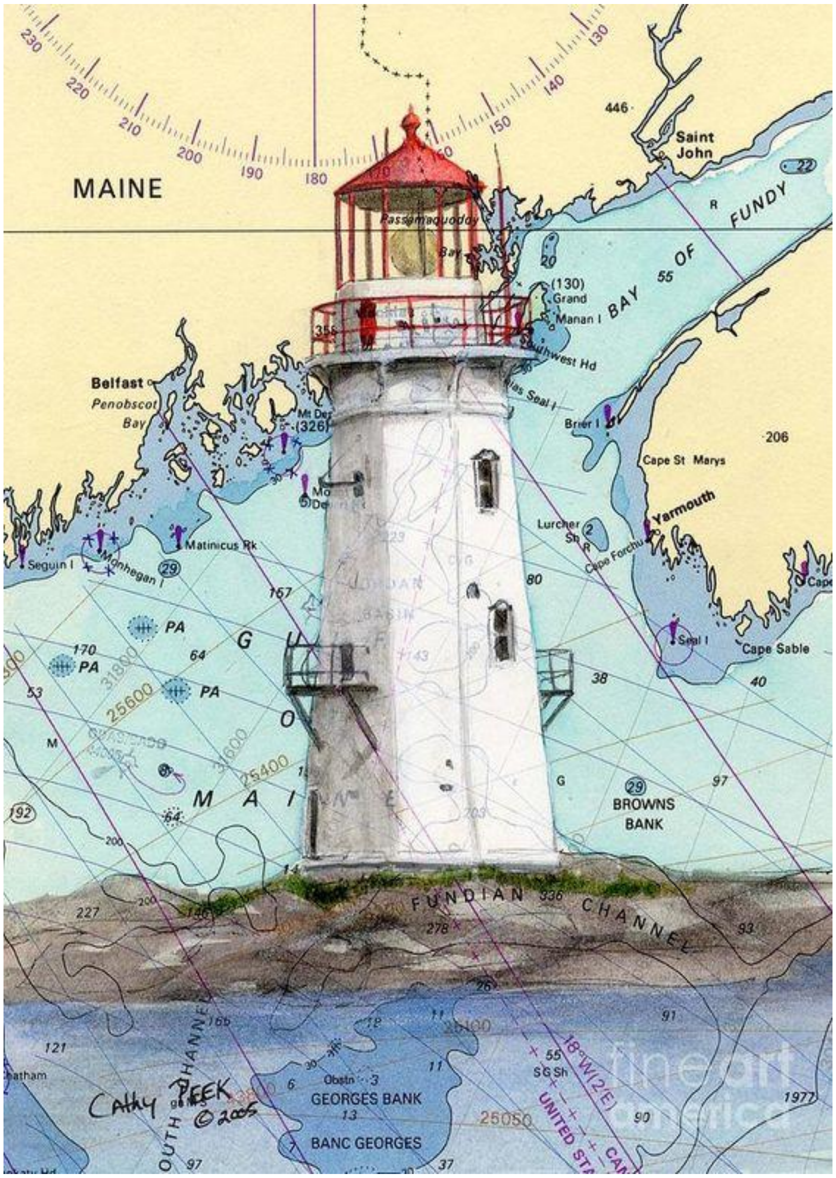
Hatteras at 193 feet, is the tallest lighthouse constructed in the United States.

The nude and the lighthouse by David Bromley



The use of cast iron in lighthouse construction probably began in the early 1840s. In 1844, a cast iron tower was built on Long Island Head in Boston Harbor. The 1848 tower at Brandvwine Shoals, the first screw pile lighthouse in the United States, had a cast iron tower. Also, the three Florida reef lights and the first Minots Ledge lighthouse. all built in the early 1850s, incorporated much cast iron in their construction. The advantages of cast iron were that it was light when compared to stone and brick, it was inexpensive, it was strong, it was water tight and it had a slow rate of deterioration. A number of cast iron towers were lined with brick for additional stability and insulation. By the close of the 19th century, cast iron towers proliferated throughout the United States. The tallest cast iron tower was the Cape

Henry light built in 1881; it is 165 feet and is still standing.

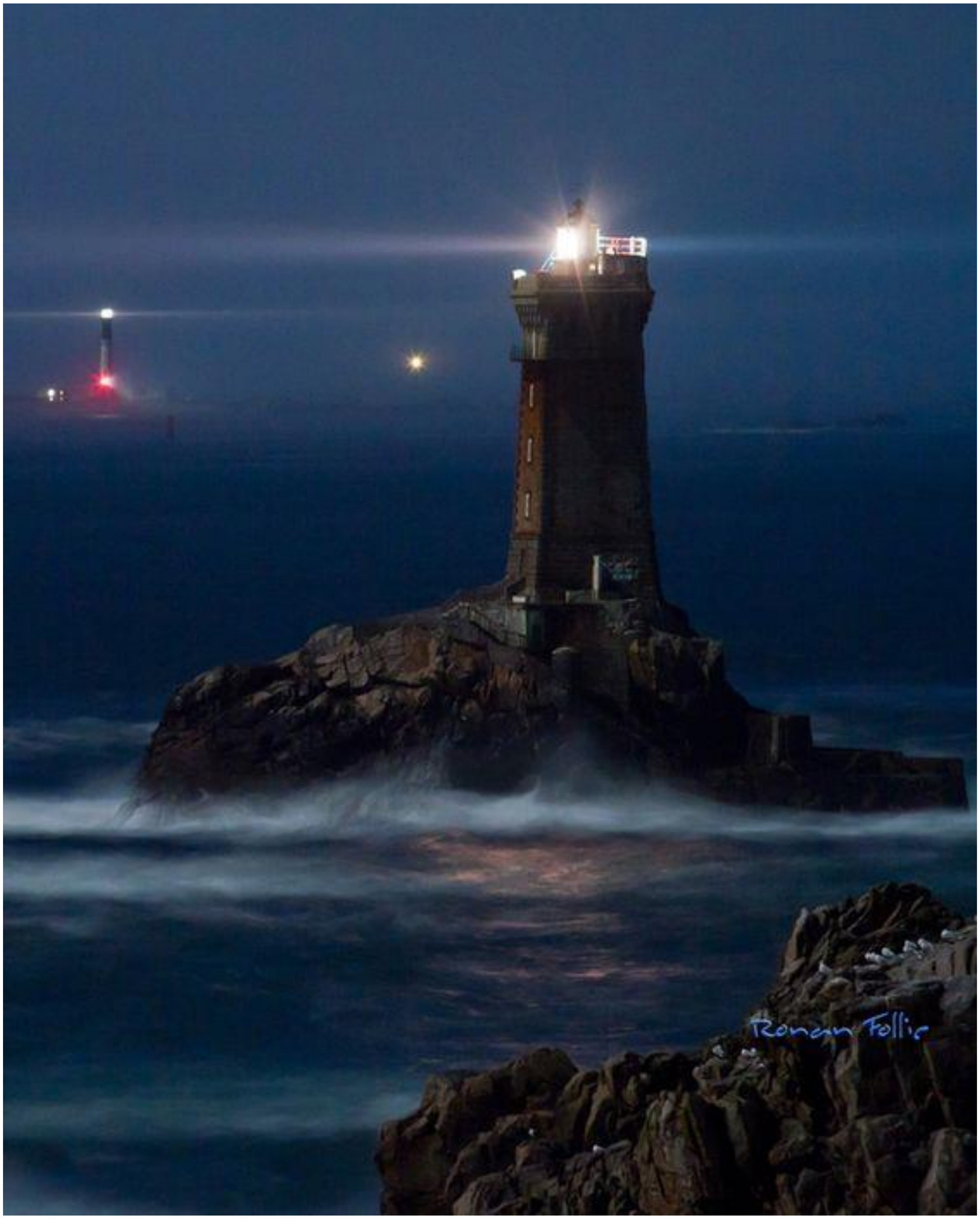


Crib foundation construction was used extensively on the Great Lakes. Wooden cribs were constructed ashore, towed to the site, and filled with stone. Once the crib had settled to the bottom, it was capped with concrete or other masonry.Frequently it was necessary to level the structure by adding weight to one side or another. From an engineering viewpoint, the two most significant crib lighthouses in the Great Lakes are Spectacle Reef and Standard Rocks. The first was completed in 1874 and the second 8 years later. Spectacle Reef is 10 miles from the nearest land and Standard Rocks is 23. Each required a number of years to complete.

Cofferdam construction was used where it was desired to build the foundation on a dry site and where it was not necessary to penetrate the seabed to any great depth. This method could only be used in very shallow water. The wooden walls of the cofferdam were constructed ashore, taken to the site, assembled into a box in the water, bolted together and sealed, and the water pumped. Workmen then entered this open-topped structure and prepared the foundation for the lighthouse.

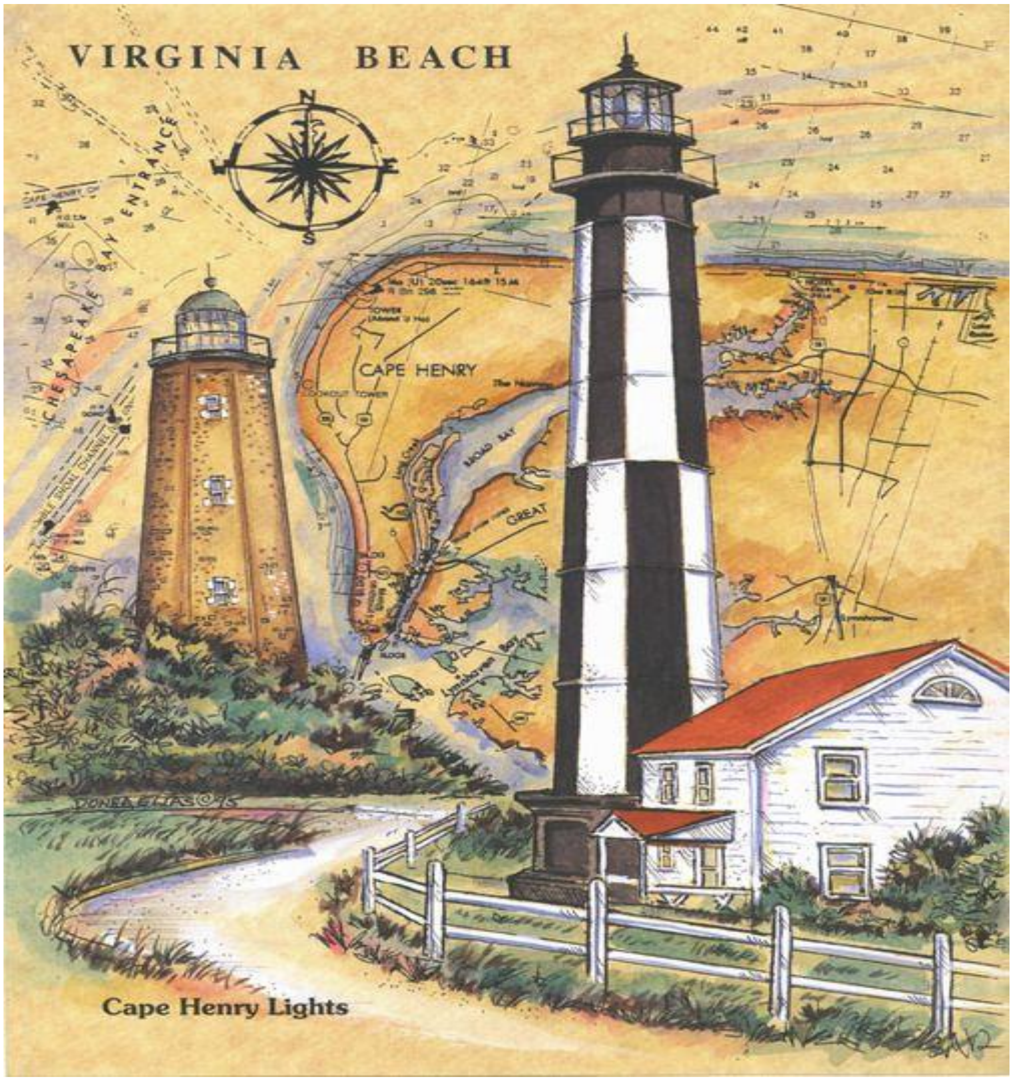
Three lighthouses were constructed upon man-made foundations built upon underwater ledges, stone by stone without the use of a crib. They were Stratford Shoal, New York; Race Rock, New York; and New London Ledge, Connecticut. These sites were exposed to strong currents which these foundations had to absorb. These lighthouses are characterized by a typical light tower, which might be found at any shore site, placed on top of a massive stone foundation designed to absorb the fury of the waves. However, the tower itself was not designed to sustain the force of waves crashing against it, as is the case for the wave-swept structure. Each of these foundations was very expensive to build. This fact, coupled with the development of the submarine site lighthouse, probably accounts for the fact that only three of this type were built.

Cast iron revolutionized the construction of lighthouses in Northern bays and sounds because it significantly reduced the cost of building a lighthouse foundation in the water to a fraction of what it had been. The screw-pile structure had revolutionized lighthouses in the bays and sounds of southern waters; however, this technology was not applicable in northern waters due to its vulnerability to swift currents and ice. The traditional method of preparing a foundation on an underwater site in northern waters was by laying and interlocking a bed of large stones weighing from three to five tons each. But this method was time consuming and expensive. The 10,000 ton foundation at Race Rock, New York, took five years to prepare and cost a quarter of a million of 1875 dollars. And the lighthouse still needed to be built. By comparison, a hollow cast-iron shell could be sunk to the seabed in water up to 30 feet and filled with sand, rock, or concrete. Cast iron was selected because of its ability to resist corrosion in salt water. A lighthouse, typically of cast iron, was then placed on top of the caisson although other materials were also used for the tower. By the 1870s these caisson lighthouses had proliferated through the northern waters of the nation. Approximately 50 caisson lighthouses were built.



Most cast-iron caisson bases were simply lowered to the seabed and filled with concrete.

However, sites where the seabed was uneven, unusually soft, or exposed to strong currents and waves, required special preparation. For these lights, known as submarine site lighthouses, a caisson containing a double bottom was sunk in position. Once stood upright, air was pumped into the caisson, forcing the seawater out through the bottom. Workmen then entered the top of the caisson through an air-lock system and prepared the foundation. The bottom rim of the caisson acted as a cutting edge which settled into the seabed as workmen excavated sand and mud from inside the caisson. Water was kept from seeping under the edge and into the work chamber by air pressure. The excavated soil was hauled out or sucked out through an airtight shaft. The workmen might sink the cast iron caisson structure as much as 33 feet below the seabed.



The first submarine, or pneumatic site lighthouse, was constructed at Fourteen Foot Bank, Delaware, in 1887. Eleven submarine site lighthouses were built. The most exposed is Sabine Bank, Louisiana, which is 15 miles off the shore in the Gulf of Mexico.

The breakwater lighthouse presented some unique challenges that were not solved until iron was introduced as a building material The breakwater lighthouse had to be relatively light in order to avoid stress on the foundation. The structure had to be strong in order to withstand the impact of the waves and vibrations and the lighthouse had to be compact because of the limited space available for the structure. Frequently, the keeper’s quarters were in town, because breakwaters were generally too small to attach the keeper’s quarters to the tower. The majority of breakwater lighthouses were constructed in the Great Lakes.

The introduction of reinforced concrete once again changed the direction of lighthouse construction. This material was in many ways superior to iron and steel. It was cheaper and required much less maintenance. Also, it was extremely strong. Many lighthouses built in places susceptible to earthquakes were made of reinforced concrete. Therefore, most major concrete towers are found on the West Coast.

The first reinforced concrete tower was built at Point Areas, California, in 1910. It is 115 feet, one of the two tallest towers on the West Coast. The tallest reinforced concrete tower is Navassa in the West Indies. This tower is 150 feet. The Brandywine Shoal Lighthouse, Delaware (1914), was the first combination of a reinforced concrete tower on a caisson base. A series of reinforced concrete towers of art-deco design were constructed in Alaska during the 1920s and 1930s. One of these, Scotch Cap, was destroyed by a tidal wave in 1946; five lives were lost. The newest reinforced concrete tower is Oak Island, North Carolina. This 169-foot tower was completed in 1958. This silo-style tower was erected by using a Swedish-developed moving slip-form method. Concrete was poured and once that section dried, the form was moved up and another section was poured. The color is integrated into the concrete. The lantern room is aluminum.

Aluminum had been introduced into lighthouse construction following World War II, primarily in the lantern room area. The Charleston tower completed in 1960 was the first structure where aluminum was extensively used in the construction of the tower. The skeleton of this 140-foot tower is made of high-strength steel and the panels are aluminum. The tower is designed to withstand winds up to 160 mph and it is the only lighthouse with an elevator.

World War II technology permitted lighthouses to be built at locations previously served by lightships. These offshore light structures are based upon technology developed in the oil industry. Their legs are driven 170 feet into the seabed. The towers are designed to withstand 65-foot seas and 125-mile-per-hour winds. Seven towers of this type have been built.[1]

These were the major evolutions in lighthouse towers.

PRE-FEDERAL ERA LIGHTHOUSES

(1716-1789)

EXAMPLES: Sandy Hook, Boston, Cape Henry......

Twelve lighthouses were built in the United States before the Constitution became the law of the land. It was at this time that lighthouse control passed from the states to the federal government. No two were constructed from the same set of plans and all were built from local materials. By examining the one which remains, and the evidence of those which have not survived, reveals that these lighthouses shared some common features.

All the early lighthouses were constructed of wood or stone. Those built of wood fell victim to fire sooner or later. The stone towers were built simply by piling one stone on top of another. These stones were held together by mortar. Since the walls apparently contained no additional support such as reinforcing rods, they had to be tapered as they rose in order for the base to support the ever increasing weight and to prevent the tower from becoming unstable. Therefore, the higher they wished to build the light, the thicker the tower had to be at the base.

Given the flat nature of east coast geography, where all pre-federal lights were built, there was a need to build the lighthouses as tall as possible. Since colonial lights peaked at about 90 feet, we may assume that this was the maximum practical height for a tower built during this era.

It is surprising how little we know about pre-Federal era lighthouses. While we have almost no construction details, we do have one remaining tower to study, that of Sandy Hook, New Jersey, and there are many unanswered questions.

Were their thick walls, up to seven feet at the base, solid or are there air spaces within them? Since the Sandy Hook light, the lone survivor does not have any weep holes to allow moisture to escape, it would seem that this structure is solid.

For those not built on rock, what type of foundations did they have? If lighthouse construction paralleled building practices of this era, first pilings were driven, then the builders laid tiers of timber diagonally to each other, and then they added a few tiers of dressed stones laid on top of the timbers. The walls were then constructed on top of this foundation.

But all of this is mere guesswork.

EARLY FEDERAL ERA LIGHTHOUSES

(1789-1820)

Examples: Portland Head, Old Cape Henry, Georgetown Harbor

Lighthouses built between 1789 and 1820 deserve close attention. 1789 was the year that the federal government took over responsibility from the states whereby the government placed the administration under the Treasury Department. 1820 is when the administrative Fifth Auditor of the Treasury became responsible for lighthouses.

President George Washington took an active interest in lighthouses but it wasn’t too long before the President had to delegate this responsibility. First the responsibility passed to the Commissioner of the Revenue and then it went to the Secretary of the Treasury. For quite some time, Albert Gallatin, the Secretary from 1801 until 1814, personally played an active role in lighthouse administration.

Hardly a year went by when one or two new lighthouses were constructed. During this era, cut stones and brick were used for the first time. This permitted the construction of taller and stronger towers because the weight could be more evenly distributed. Of the first forty towers built, only a handful survive today. These include Portland Head (1790), the old abandoned Cape Henry tower (1792), and Georgetown Harbor (1795). Most of the early federal lighthouses did not survive the U.S. Civil War. Considering that the builders were not plagued with the teething problems of any new technology and that half of these towers were built in the north where a solid foundation could usually be found, this is not really an impressive record of survival.

Of the first forty masonry towers constructed in the United States only eleven survive.

THE FIFTH AUDITOR OF THE TRESURY'S LIGHTHOUSES

(1820-1852)

Examples: Matinicus

A villain emerged from the Camelot-like interpretation of the early days of lighthouse construction; it is the Fifth Auditor of the Treasury, Stephen Pleasanton. From 1820 through

1852, he was responsible for the administration of the lighthouses. Lighthouse administration had become too large to remain a direct responsibility of the Secretary of the Treasury and was assigned to the Fifth Auditor.

The Fifth Auditor of the Treasury was a bookkeeper and a financial zealot. After all, one would hardly expect to find a philanthropist in the Treasury Department. The Fifth Auditor prided himself that for many years he was able to return funds appropriated for the construction and repair of lighthouses to the Treasury unspent. Given todays Federal budgets many would argue that this brand of Civil Servant is extinct. The Fifth Auditor, however, was a lighthouse novice when assigned the task, and unfortunately he did little to improve his knowledge of lighthouse technology during his 32-year tenure.

This period, which begins in 1820, might well be labeled the era of "the lowest bidder," and the lighthouses built during this period were inferior structures constantly in need of replacement. In addition, the lighting system used was not only grossly inferior too, but far less expensive than that employed in Europe.

A July letter from Lieutenant David D. Porter, later of Civil War fame, summarized the inadequacy of American lighthouses.

"Hatteras light, the most important on our coast is, without a doubt, the worst light in the world. …The first nine trips I made I never saw Hatteras light at all, though frequently passing within sight of the breakers, when I did see it, I could not tell it from a steamer's light, excepting that a steamer's lights are much brighter."

Not surprisingly, there are few examples of the Fifth Auditor lighthouses which have survived today. However, the Matinicus Rock light does show evidence of this era, and the evolution of this light is a good example of the fate of most constructed during the rein of the Fifth Auditor.

The current tower is the third lighthouse to be built on Matinicus Rock. You can see the remains of the second tower which has been capped. The second tower, in fact, did nothing to solve the problems of the first tower. Both were far too short and the towers were too close together. The problems were not solved until the third structure was constructed which is the present lighthouse.

Being a bureaucrat I am compelled to offer a few words in defense of the Fifth Auditor. Remember, the survival record of towers constructed by earlier administrators wasn't really much better. In 1820, when the Fifth Auditor became responsible for the lighthouses only, 3 of the 12 pre-Federal towers were standing and during his tenure, the Fifth Auditor had to rebuild many of the towers constructed by his immediate predecessors.

Adding to the Fifth Auditor's problems was the fact that during his tenure as the administrator of lighthouses, the U.S. continually added territories that required lighthouses needing the most successful technology of the day. The massive stone towers built in the past, had little value. For example, of the 40 or so brick towers built in the South, at least 25 either blew over or sank into the soft ground.

THE ERA OF THE LIGHTHOUSE BOARD

(1852-1903)

In 1851 a special committee of professionals, appointed by Congress, conducted an investigation into the lighthouse system and concluded that it was grossly inadequate.

In 1852 Congress created a nine-member Lighthouse Board and with it a new era in American lighthouse construction began. During the next few decades American lighthouse construction went through its most dynamic period. As we examine each advance in lighthouse construction, you will see that the specific technology already existed, but it had not yet been applied to lighthouse construction.

PILE FOUNDATION

A Quaker and wealthy Liverpool merchant, John Phillips, erected a lighthouse on Smalls Rock in 1773, in the British Channel off the west coast of Wales. Instead of hiring an engineer to design the structure, he chose a musical instrument maker, Henry Whiteside, who built the lighthouse on piles rather than using conventional masonry tower. Phillips' choice and Whiteside's design were to prove revolutionary. Construction began in June 1775 and, when finished, the lighthouse consisted of nine oak posts each twenty-four inches in diameter and forty feet in length with a small two-story octagonal wooden cabin built on top. The first floor was where the keepers lived and the top floor housed the light. It stood for eighty-five years.

Brandywine Shoal Lighthouse, built in 1828 in Delaware Bay, and destroyed in ice in the same year, is an example of a standard wooden straight-pile driven foundation. One of the last wooden straight-pile lighthouses built was the Desdemona Sands Lighthouse, Columbia River, Oregon. It was completed in 1902 and dismantled shortly after World War II.

PROTECTED SCREW PILE LIGHTHOUSES

(1850- ?)

Example: Drum Point
More familiar as the protected, screw-pile lighthouse. It was introduced into the United States in 1850 during the closing days of the Fifth Auditor's reign.

Alexander Mitchell invented the screw-pile, a major improvement over the standard straight pile. With his son, he patented his cast iron screwpile design in the 1830s. By 1840 Mitchell combined his cast iron screwpile moorings with another pile construction technique and built the first screwpile lighthouse type at the mouth of the Wyre, an important harbor in Lancashire, England. Mitchell used 36-inch-diameter wooden timbers on whose bottoms were attached his cast iron screwpile devise. Completed in 1841, his structure was the first lighthouse to be built upon a screwpile foundation madeentirely of iron.

A protected, screw-pile lighthouse was typically a light-weight, wooden tower on iron stilts, the legs of which are tipped with cork-screw like flanges. These legs are turned into the soft ground of protected waters, such as bays and sounds. This new type of lighthouse was dependent upon the development of wrought-iron columns for the legs and cast-iron for the screw-like flanges. This technology permitted the construction of lighthouses on sites too soft to support the weight of a heavy tower.

The pile technology as mentioned was introduced in the United States at Brandywine Shoals in the Delaware Bay in 1850. Within a few decades, perhaps as many as 100 protected screw-pile lighthouses were built throughout the United States, principally in the Carolina sounds and Chesapeake Bay. This type of structure was particularly suited to slow moving, shallow water which was not subject to freezing. Screw-pile lighthouses could also be found in the Gulf of Mexico and one was even built in the Great Lakes at Maumee Bay, but survived only one season.

The principal enemies of this type of structure were fast-flowing water, ice, and fire.

The screwpile lighthouse construction technique became especially popular after the American Civil War when the Lighthouse Board adopted a policy to replace light vessels in the interior waters with screwpile lighthouses.

Today, four of three screw-pile lighthouses survive, all in the Chesapeake. They are Thomas Point, Drum Point which now rests at the Calvert Maritime Museum, Hooper Strait at the Chesapeake Bay Maritime Museum, and Seven Foot Knoll, recently moved to Baltimore.

EXPOSED, SCREW-PILE LIGHTHOUSES

(1852-1880)

Examples: Carysfort Reef (1852); Sombrero Key (1857); Fowey Rocks (1873)

The screw-pile lighthouse design for exposed sites evolved two years after its less complex cousin, the type built for protected waters.

The exposed, screw-pile lighthouse was designed for and used in the Florida coral reefs. This structure varied in two important ways from the style designed for the protected bays and sounds. First, the lighthouse structure was a tall, skeleton iron tower and not a squat wooden structure. The screw-pile lighthouse in the bays and sounds did not need to project their lights more than a few miles, so the height of the lens was not a major concern. But this was not true for the Florida reef lights. These structures were to be major coastal lighthouses with first order lenses weighing a number of tons. Therefore, they had to be tall structures. The second major difference was in the screw flange. Large, iron foot plates were added above the screw tip in order to diffuse the pressure caused by the weight of the tower.

The first screwpile skeletal tower type to be built was the Carysfort Reef Light, off Miami, Florida, designed by I. W. P. Lewis. It was started in 1848 and completed in 1852. The entire structure was first erected in Philadelphia to prevent the need of fitting the parts together at the isolated site and it cost $105,069 to complete. This was the first tall tower built on the dangerous stretch of reefs between Cape Florida and Key West, Florida, and the oldest existing screwpile type light in the United States. Carysfort Reef Lighthouse, with its skeletal foundation, presented relatively little resistance to wind and waves and served as a prototype for the string of lights that now mark the reefs off Florida.

Six screw-pile lighthouses for exposed sites were constructed in the Florida reefs, three before the Civil War and three afterward. Also, one light was built in the Gulf of Mexico at Ship Shoal, Louisiana, in 1858. Those built before the war are much simpler in appearance than those built two decades later.

Straight-Pile Tubular Skeletal Towers

A close cousin to the screw-pile lighthouses were the straight-pile skeletal towers. Straight-pile tubular skeletal tower lights were built, usually of cast iron but also with wrought iron piles, both on shore and off shore, typically on soft bottoms such as mud, sand, and swamp. Early surviving examples of non-screwpile tubular skeletal tower types include: Sombrero Key Lighthouse (1858), Florida, built on iron piles; and the Southwest Reef Lighthouse (1858), Louisiana, also built on iron piles.

WAVE-SWEPT LIGHTHOUSES

(1850-1906)

Examples: Minots Ledge, Saint Georges Reef, Mile Rock

Another lighthouse type is the offshore wave swept tower built on rocks just above or slightly below the ocean’s surface and subjected to the full fury of the sea. In 1759, John Smeaton, an

Englishman, built the first successful wave swept tower in the English Channel at Eddystone Rock. This was the first interlocking masonry block tower. Later Smeaton developed (after the Romans) a cement that would set up in water. These two inventions revolutionized open sea lighthouse construction and remained the principal method for their construction until concrete and steel came into use.

The wave-swept lighthouse probably conforms closer to our mental image of the classical lighthouse than any other type. But only a few were built. The greatest engineering achievement in this country, given the difficulty of the task, and the technology available, had to be the construction of Minots Ledge lighthouse.

The first attempt to put a lighthouse on Minots Ledge was during the closing days of the Fifth Auditor. An iron tower on stilts was placed there and was destroyed by a storm just over one year after completion. The wrought-iron legs were embedded in the rock ledge. But during a violent storm in April 1851 the legs broke, washing the two keepers to their death.

The second Minots Ledge structure was begun in 1855 and completed in 1860. A good part of its foundation is underwater. Work on preparing the ledge took three years before the first course of stones was laid. The granite blocks are dove-tailed together and bounded vertically by bolts. The first forty feet of the tower are solid stone. This tower is ninety-seven feet tall and has been topped by waves several times. It is the most expensive lighthouse that was ever built. In the late 1980s the Coast Guard removed the top twenty feet, remortered the stones and replaced them. Of particular interest was its early signal—a single flash; a pause-then 4 flashes-a pause- and then 3 flashes. Because of this signal, it was called the "I Love You Lighthouse" symbolizing the eight letters in the phrase.

Other examples of wave swept lights are St. Georges Reef near Crescent City, California, and Mile Rock near San Francisco, California.

TALL BRICK TOWERS

(1857-1876)

Examples: Pensacola, Fire Island, Cape Hatteras

When the 1803 Cape Hatteras Lighthouse tower was heightened to 150 feet in 1854 it was the first of the original "tall tower" lights to be built in the United States. The original tower was replaced by a 1870 tower that stretches over 190 feet above the ground.

Beginning with the new Lighthouse Board in 1852, they began the construction of brick towers of increasing height. By 1859 nine brick towers over 160 feet had been built and six more were constructed after the Civil War.

These towers are conical in shape, except for Cape Romain, South Carolina, which is six-sided. None of the towers which they replaced had topped 100 feet.

One would suspect that some engineering or technological breakthrough had occurred in the 1850s which allowed this more than 60-foot increase in the height of a coastal tower. This does not seem to be the case. Apparently, some had solid walls and others were constructed with air spaces between inner and outer walls. Yet these construction techniques had existed long before the 1850s.

Then why did it take until 1850 to increase the height of towers? Permit me to suggest a few possible reasons why towers grew at this time. Perhaps engineers had improved their undertaking of mathematics and this permitted them to conclude that the existing technology could support another sixty feet. More likely the Lighthouse Board made available the money for the additional sixty feet while the Fifth Auditor had not. Another possibility is that perhaps the introduction of the Fresnel lensenow made it practical to raise the towers.

All fifteen towers were built along the Atlantic Coast, as far north as Fire Island, New York, and as far south to Dry Tortugas, Florida. The tallest of these towers, Cape Hatteras at 193 feet, is also the tallest lighthouse constructed in the United States. Interestingly, all but one of the fifteen towers remain standing—although erosion is threatening several of these.

CAST IRON LIGHTHOUSES

Examples: Cast Iron Lighthouses

The use of cast iron in lighthouse construction probably began in the late 1830s or early 1840s.

In 1844 a cast iron tower was built on Long Island Head in Boston Harbor. The 1848 tower at Brandywine shoals, the first screw pile lighthouse in the United States, had a cast iron tower. Also, the three Florida reef lights and the first Minots Ledge lighthouse, all built in the early 1850s, incorporated much cast iron in their construction.

The advantages of cast iron were that it was light when compared to stone and brick, it was inexpensive, it was strong, it was water tight and it had a slow rate of deterioration. A number of cast iron towers were lined with brick because engineers of the day could not adequately calculate the stress load and added the brick as a safety factor. Cast iron towers were especially adapted to locations where a relatively light pile structure was required in mud, sand, swamp, or coral. In these locals, skeletal tubular iron towers were often built. At least one dressed stone light was sheathed in iron plate. It was Destruction Island Lighthouse, Washington, built in 1891. It was gradually accepted that the cast-iron built lighthouses, though cheaper to build than masonry, were not as structurally sound for exposed sites, but rather more acceptable for secured headlands and harbor locations.

CRIB LIGHTHOUSES

Examples: Spectacle Reef, Poe Reef, White Shoal

Beginning in the 1870s crib foundation construction was used extensively on the Great Lakes. Wooden cribs were constructed ashore, towed to the site, and then filled with stone. Once the crib had settled to the bottom, it was capped with concrete or some other masonry. Frequently once the crib had settled it was necessary to level the structure by adding weight to one side or another.

From an engineering view point, the two most significant crib lighthouses in the Great Lakes are Spectacle Reef and Standard Rocks. The first was completed in 1874 and the second eight years later. Spectacle Reef is 10 miles from the nearest land and Standard Rocks is 23. Each required a number of years to complete.

White Shoal lighthouse, guarding the western entrance of the Straits of Mackinac, is also crib type. Its foundation is a timber crib 72 feet square, supporting a reinforced concrete pier which extends 20 feet above the lake level. The 105 foot tower, completed in 1910, is steel, backed with brick, and faced with terra cotta.

COFFERDAM LIGHTHOUSES

Examples: Robbins Reef, Craighill Channel, Upper Range
Cofferdam construction was used where it was desired to build the foundation on a dry site and where it was not necessary to penetrate the sea-bed to any great depth. This method could only be used in very shallow water. The wooden walls of the cofferdam were constructed ashore, taken to the site, assembled into a box in the water, bolted together and sealed, and the water pumped. Workmen then entered this open-topped structure and prepared the foundation for the lighthouse. The light pictured here is the Robbins Reef Light.

UNDER-WATER FOUNDATION LIGHTHOUSES

Examples: Stratford Shoal, Race Rock, New London Ledge
Three lighthouses were constructed upon man-made foundations built upon under-water ledges. There were Stratford Shoal, Race Rock, and New London Ledge. The under-water islands upon which these lighthouses were built, were raised stone by stone and had to absorb the constant pressure of strong currents.

Under-water foundation lighthouses were horrendously expensive to build and took years to prepare. Thousands of stones weighting 3 to 5 tons apiece had to be laid under water at each site. The 10,000 ton foundation at Race Rock took 5 years to prepare and cost to build $250,000 in 1875 just to prepare the foundation. And the lighthouse tower still needed to be built. In these lighthouses, the tower itself did not need to be designed to sustain the force of waves crashing against it, as was the case for the wave-swept lighthouses that we looked at earlier.

CAISSON LIGHTHOUSES

Examples: Bloody Point, Brandywine Shoal, Lubec Channel
The ability to roll iron into large plates revolutionized the construction of lighthouses in northern bays and sounds because it significantly reduced the cost of building a lighthouse foundation in the water to a fraction of what it had been. The screw-pile structure had revolutionized lighthouses in the bays and sounds of southern waters; however, this technology was not applicable in northern waters due to the screw-pile's vulnerability to swift currents and ice.

The caisson construction method for lighthouses is based on the idea developed by Lawrence Potts, an English physician and inventor, who in 1845 sank a section of hollow tubing from the surface of the ocean to the sea floor. He then attached a powerful pump to the open end extending above the water and as he pumped air and water from the tube it drew up sand which allowed the tube to sink deeper into the sea bottom. The method was then employed in 1850 during the construction of bridge support towers at Rochester, New York. Workmen soon discovered that large rocks obstructed the descent of the tube so the engineer in charge reversed Pott's process. He pumped air into the tube forcing the water out so his men could descend into the tube and remove the rocks, sand, and mud, allowing the tube to sink under its own weight into the river.

As noted, the expense of preparing a foundation at an underwater site was prohibitively expensive. By comparison a hollow rolled-iron shell could be sunk to the sea-bed in water up to thirty feet and filled with sand, rock, or concrete. Iron was selected because of its ability to resist corrosion in salt water. A lighthouse, typically of iron, was then placed on top of the caisson.

The first caisson lighthouse built in the United States is believed to be the Duxbury Lighthouse in Massachusetts. It was built in 1872, at the end of a breakwater in relatively shallow water. By the 1870s, these caisson lighthouses had spread through the northern waters of the nation. Approximately, fifty caisson lighthouses were built.

SUBMARINE SITE (PNEUMATIC CAISSONS) LIGHTHOUSES

Examples: Fourteen Foot Bank, Smith Point, Wolf Trap
Most of the caisson bases were simply lowered to the sea-bed and filled with concrete. However,

sites where the sea-bed was uneven, unusually soft, or exposed to strong currents and waves required special preparation.

For these lights, known as submarine site or pneumatic lighthouses, a caisson containing a double bottom was sunk in position. Once stood upright, air was pumped into the caisson, forcing the sea water out through the bottom. Workmen then entered the top of the caisson through an air-lock system and prepared the foundation. The bottom rim of the caisson acted as a cutting edge which settled into the sea-bed as workmen excavated sand and mud from inside the caisson. Water was kept from seeping under the edge and into the work chamber by air pressure. The excavated soil was hauled out or sucked through an airtight shaft. The workmen might sink the caisson structure as much as 33 feet below the sea-bed floor.

Often within the caisson, a cellar was built within the upper 12 feet and enclosed with at least 6 feet of thick masonry or concrete walls. Occasionally recessed windows also were added for lighting purposes. These cellars were often used for fuel storage such as wood or coal bins and often a cistern for water collected from the roof gutter and down spout system. The first level was usually partitioned into a sitting room, kitchen, and storage area, and completely surrounded by a gallery. The second and sometimes third floor was dedicated to sleeping areas and storage. The level directlybelow the lantern room was the watch room.

Caisson lighthouses were more complicated and on average about four to five times more expensive to build than screwpile lights but they were better able to withstand the pressure of flowing ice.

The first submarine, or pneumatic, site lighthouse was constructed at Fourteen Foot Bank, Delaware, in 1887. The pneumatic method had been used 21 years earlier to repair the timber crib foundation at Wangoshance light on Lake Michigan. Eleven submarine site caisson structures were built in all. The most exposed in Sabine Bank, LA, which was 15 miles offshore in the Gulf of Mexico and is known as the "spark plug" of the Gulf.

BREAKWATER LIGHTHOUSES

Examples: Delaware Breakwater, Grand Haven Pier, Cleveland Harbor

The breakwater lighthouse presented some unique challenges that were not solved until iron was introduced as a building material.

The breakwater lighthouse had to be relatively light in order to avoid stress on the foundation; the structure had to be strong in order to withstand the impact of the waves and vibrations; and the lighthouse had to be compact because of the limited space available for the structure. Frequently, the keepers quarters were in town, because breakwaters were generally too small to attach the keeper's quarters to the tower.

The majority of breakwater lighthouses were constructed in the Great Lakes.

SKELETON TOWER LIGHTHOUSES

Examples: Cape Charles, Marblehead, Cape Fear Sturgeon Bay
The skeleton tower, first made of iron and later steel, found great favor with the Lighthouse Board in the second half of the 19th century. The structure could be pre-fabricated and taken to the construction site in pieces. The height of the tower could be increased simply by adding sections to the bottom. Also, this type of tower offered low wind resistance, a definite asset at windy locations. It should come as no surprise that the tallest of these towers are found in areas frequented by hurricanes.

The tallest skeleton towers were Cape Charles and Hog Island, Virginia, built in the 1890s. These towers were 191 feet tall--just two feet shorter than the tallest tower in the country, the brick one at Cape Hatteras. The Cape Charles tower is still standing.

At least in theory, the skeleton tower could be disassembled and moved to a new location should the need arise. Many skeleton towers remain today. The one at Coney Island, New York, is given special notoriety by the presence of the last civilian lightkeeper, Frank Schubert.

REINFORCED CONCRETE LIGHTHOUSES

(1908-1948)

Examples: Point Arenas, Cape Decision, Cleveland Ledge, Oak Island
The introduction of reinforced concert once again changed the direction of lighthouse construction. This material was in many ways superior to iron and steel. It was cheaper and required much less maintenance. Also, it was extremely strong. Many lighthouses built in places susceptible to earthquakes were made of reinforced concrete. Therefore, most major concrete towers are found on the west coast.

Reinforced concrete towers began to replace brick masonry towers at the beginning of the 20th century. The first reinforced concrete tower was built at Point Areas, California, in 1910. It is 115 feet tall, one of the two tallest towers on the West Coast. The tallest reinforced concrete tower is Navassa in the West Indies. This tower is 150 feet tall. A series of reinforced concrete towers of art deco design were constructed in Alaska during the 1920s and 1930s. One of these, Scotch Cap, was destroyed by a tidal wave in 1946; killing five men.

The newest reinforced concrete tower is Oak Island, North Carolina. This 169-foot tower was completed in 1958. This silo-style tower was erected by using a Swedish-developed moving slip-form method. Concrete was poured and once that section dried, the form was moved up and another section was poured. The color is integrated into the concrete. The lantern room is aluminum.

OFF-SHORE STRUCTURES

Examples: Buzzard Point, Brenton Reef, Ambrose
Post World War II technology permitted lighthouses to be built at locations previously served by lightships.

These off-shore light structures are based upon technology developed in the oil industry. Their legs are driven 170 feet into the seabed. The towers are designed to withstand 65 foot seas and 125 miles per hour winds. Seven towers have been built and all have either been removed or are scheduled to be removed in the next several years.

THE ALUMINUM LIGHTHOUSE

(1960—??)

Aluminum was introduced into lighthouse construction following World War II, primarily in the lantern room area. The Charleston tower completed in 1960 was the first structure where aluminum was extensively used in the construction of the tower.

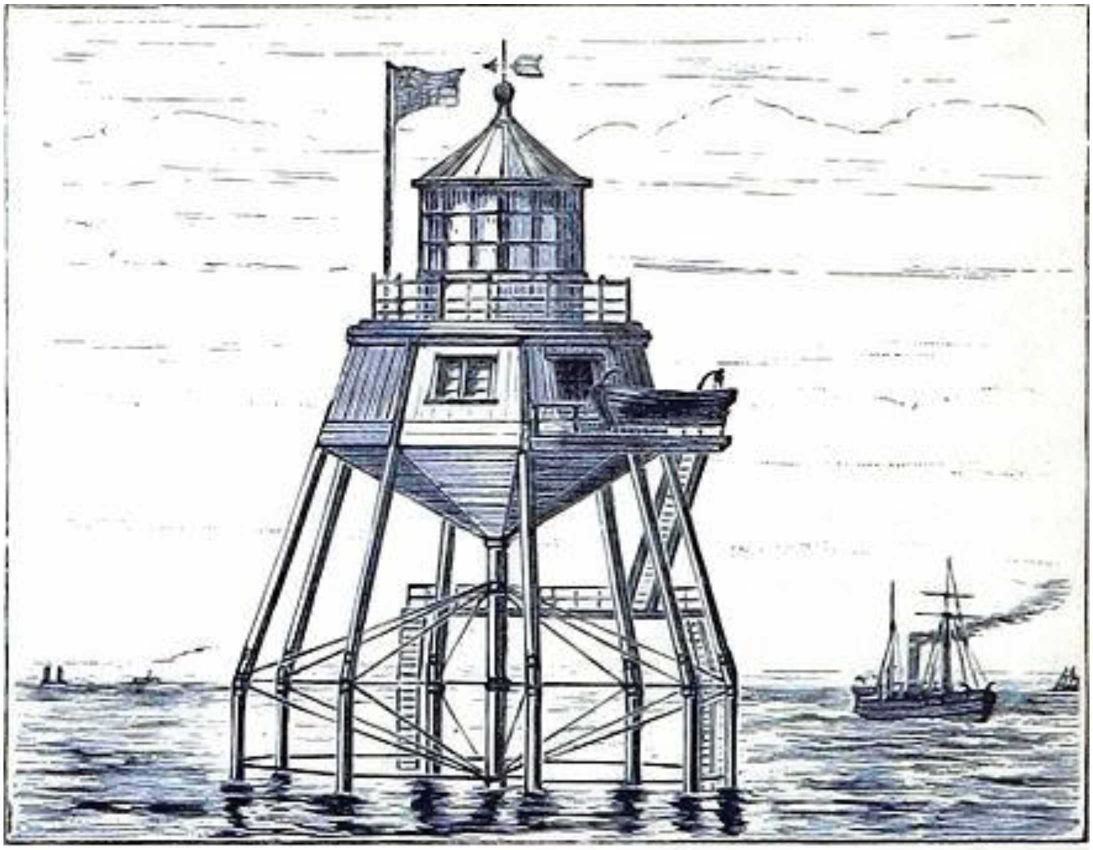
The skeleton of this 140 foot tower is made of high strength steel and the panels are aluminum. The tower is designed to withstand winds up to 160 mph and it is the only lighthouse in the United States with an elevator.

FIBERGLASS TOWERS

In an effort to keep maintenance costs down, the English introduced the concept of the fiberglass tower which was later adopted by the Coast Guard. The color of the tower is molded into the plastic with pigments, so painting is not necessary. Little if any metal is used in order to keep saltwater corrosion to a minimum. The light lens is plastic and no storm panes are required for protection. The result is very low maintenance light towers. The first use in the United States of a fiberglass tower was apparently in northern California in the 1960s. Three were built in New England in the early 1980s: Great Salt Pond Light, Block Island, Rhode Island; Deer Island Light, Boston Harbor, Massachusetts; and Cape Code Cannal Breakwater Light, Massachusetts. The first plastic lighthouse, Deer Island Light, a white tower built in 1982, replaced an iron tower on a caisson. It was replaced by a red-brown plastic tower in 1984.

CONCLUSION

Large Navigational Buoys, LORAN, and global positioning have all helped to diminish the importance of lighthouses as guides for mariners. Lighthouses, however, are and will always be ery personal. Everyone approaches them from a different perspective.



Maplin Screw Pile Lighthouse.

During the colonial period of American history, lighthouses, beacons. and similar aids to navigation were established from time to time in local areas to aid ship borne commerce. However, responsibility for these navigational aids did not extend beyond the boundaries of an individual colony. and there was no attempt to coordinate lighthouse placement and construction with neighboring colonies. Soon after its formation, the National Government determined that aids to navigation were a concern for the entire country and needed the supervision of a central office. By an act of August 7, 1789, the National Government assumed responsibility for all aids to navigation along the coasts and took over all lighthouses then in operation or under construction. The Secretary of the Treasury. and the Commissioner of Revenue under his supervision, were responsible for the early development of a Lighthouse Service. In 1820 lighthouses became the responsibility of the Fifth Auditor of the Treasury, Stephen Pleasanton, who came to be popularly called the General Superintendent of Lighthouses. He directed lighthouse work until 1852. Pleasanton's field representatives were the local collectors of customs, who were given the title Superintendent of Lights. Their duties included the selection of sites for aids to navigation, supervision of construction contractors, and authorization of repairs. Because these officials had little or no construction experience, the design of structures largely was left in the hands of contractors. By 1838 concerns about the quality of illumination along the coasts, the proper siting of navigation aids, and the advances being made by other countries led

Congress to seek the advice of naval officers. and the military took on a much larger role in the "lighthouse establishment." Responsibility for the construction of six lighthouses was taken from the Lighthouse Service and granted to the Army Corps of Engineers in 1847. Eventually the local collectors of customs lost all their responsibilities relating to lighthouses. A major change occurred when by an act of August 31, 1852, a ninemember Lighthouse Board was created within the Treasury Department to take over administration of the Lighthouse Service. The Lighthouse Board created in 1852 was composed primarily of naval and Army engineer officers. The country was divided into twelve new lighthouse districts (increased to sixteen districts by 1886 and nineteen by 1910). each with an inspector who had overall responsibility for building lighthouses, keeping them in repair, and purchasing and maintaining illuminating apparatus. Inspectors (later called superintendents) were frequently naval officers, and their administrative duties came to include the disbursal of funds, supervision of lighthouse keepers, and inspection of each light station every three months. Within a few years the board found it necessary to appoint an Army engineer in each district to share the work of the inspector. The engineers handled the building and repair of the light stations. The Lighthouse Board was transferred to the

Department of Commerce and Labor on July 1, 1903. By an act of June 17, 1910, the Bureau of Lighthouses was established to supersede the old board and operate under a single administrative head called the Commissioner of Lighthouses. One of the intentions of the act was to reduce the role of the military in lighthouse supervision, although 1 I Army engineers continued to manage construction and repair work in each district. Decisions relating to location, design, construction, and inspection of new lighthouses were the responsibility of the Engineering Construction Division of the Bureau. The Bureau of Lighthouses was assigned to the Department of Commerce when it was separated from the Department of Labor in 1913. On July 1, 1939, the Bureau of Lighthouses was abolished, and its functions were transferred to the United States Coast Guard. The Coast Guard added lighthouse supervision to its responsibilities for maintaining lifesaving stations, inspecting vessels, and enforcing customs laws. On April 1, 1967, the Coast Guard, which had been part of the Department of the Treasury, was transferred to the Department of Transportation. The Drawings Section 14 of the 1852 act creating the Lighthouse Board specified that it was the duty of the board "to cause to be prepared by the engineer secretary. ..or by such officer of engineers of the army as may be detailed for that service, all plans, drawings, specifications, and estimates of cost, of all illuminating and other apparatus, and of construction and repair of towers, buildings, etc., connected with the lighthouse establishment." About 1862 a number of standard plans of typical lighthouses and pieces of illuminating equipment were lithographed as guides for possible use in various locations. (A set of these lithographs is described item-by-item at the end of Part I of the list.) After 1910 when the Bureau of Lighthouses received a request for a new lighthouse, operating procedures called for the creation of reports and drawings at various stages. First, the request was turned over to one of the district superintendents who would submit a report on its feasibility and usefulness.

On a favorable report, the district superintendent would be instructed to prepare a preliminary survey to determine the kind of station required and to estimate the cost. An appropriation request was then submitted to Congress. If approved, the superintendent was instructed to make a detailed survey and draw up systematic plans for the new structure. After their approval by the bureau, plans were returned to the district office for construction. Some plans were maintained by the central office, and others were maintained by the district offices. Although the plans and specifications were prepared by the government, construction work usually was completed under contract. If contractors could not be engaged due to the remoteness of the station or to hazards involved, construction was undertaken by the bureau. floor levels;

REFERENCES

1. **Historic Lighthouse Preservation Handbook,By Candace Clifford**

CHAPTER IX

EVOLUTION OF THE LIGHT SOURCE AND LENSES

From the earliest days in Alexandria (circa 300 BC) when Euclid described the laws of reflection in ***Optica***, the science of optics has fascinated and challenged society's most brilliant minds. The earliest pioneers in optics reached for the stars with difficulty as they developed crude lenses and mirrors for their telescopes while other investigators focused on the hidden microscopic world through aberration-plagued compound optical systems that hampered early microscopes.

Today, millions of the optically-challenged need be thankful to these pioneers for the eyeglasses, contact lenses, and other advances that have evolved from innovations dating back as early as 1303 when Bernard of Gordon, a French physician, wrote about the use of spectacles as a way of correcting long-sightedness (hypermetropia). From the earliest compound microscopes, enabling anatomists to describe the properties of blood cells, to the modern electron and scanning laser confocal microscopes and NASA's Hubble space telescope, the science of optics has helped us understand the world around us, our bodies, and the diseases we face in our daily lives.

Whether it is Polaroid instant photos, sunglasses, disposable contact lenses, the ubiquitous television, videos, or the more recent compact discs, fiber optics communications, and digital cameras, we all reap the harvest of seeds planted by pioneers in the optical sciences. Tribute is paid to these heroes through brief biographies that acknowledge their tremendous accomplishments and how they have affected our civilization.

A Fresnel lens (pronounced fray-nel) is a type of lens invented by French physicist Augustin-Jean Fresnel.Originally developed for lighthouses, the design enables the construction of lenses of large aperture and short focal length without the weight and volume of material which would be required in conventional lens design. Compared to earlier lenses, the Fresnel lens is much thinner, thus passing more light and allowing lighthouses to be visible over much longer distances..

Several manufacturers of lighthouse lenses commonly seen are:

- Chance Brothers & Co, Birmingham UK
- Henry Lepaute, Paris France which later became Barbier, Bernard and Turenne (BBT)
- Pintsch, Germany

The Fresnel lens (pronounced /freɪˈnɛl/) focused 85% of a lamp's light versus the 20% focused with the parabolic reflectors of the time. Its design enabled construction of lenses of large size and short focal length without the weight and volume of material in conventional lens designs.

Fresnel lighthouse lenses are ranked by *order*, a measure of refracting power, with a first order lens being the largest, most powerful and expensive; and a sixth order lens being the smallest. The order is based on the focal length of the lens. A first order lens has the longest focal length, with the sixth being the shortest. Coastal lighthouses generally use first, second, or third order lenses, while harbor lights and beacons use fourth, fifth, or sixth order lenses.

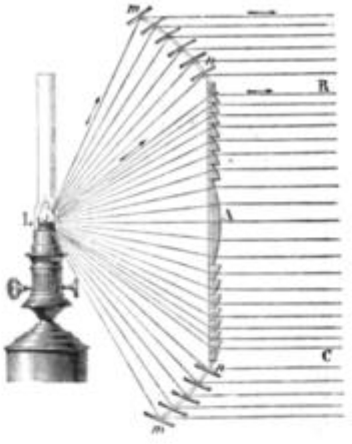
Some lighthouses, such as those at Cape Race, Newfoundland, and Makapuu Point, Hawaii, used a more powerful hyperradiant Fresnel lens manufactured by the firm of Chance Brothers.

In recent times, many Fresnel lenses have been replaced by rotating aerobeacons which require less maintenance. In modern automated lighthouses, this system of rotating lenses is often replaced by a high intensity light that emits brief omnidirectional flashes (concentrating the light in time rather than direction). These lights are similar to obstruction lights used to warn aircraft of tall structures. Recent innovations are "Vega Lights", and initial experiments with light-emitting diode (LED) panels.

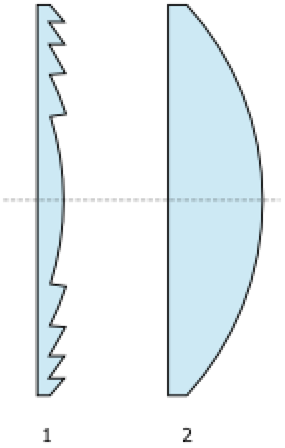
A **Fresnel lens** is an optical lens, which was originally developed for Lighthouses. It is named after its inventor, French physicist Augustin-Jean Fresnel. The name is pronounced /freɪˈnɛl/ (fray-NELL), the 's' is silent. Before Fresnel, Buffon and Condorcet proposed a similar design, as a way to make large burning lenses.

The design allows the construction of lenses of large aperture and short focal length without the weight and volume of material that would be required in conventional lens design. Compared to earlier lenses, the Fresnel lens is much thinner. More light can pass through. Lighthouses that use these kind of lenses can be seen from farther away.

Description



How a spherical Fresnel lens collimates light



1: Cross section of a spherical Fresnel lens
2: Cross section of a conventional spherical plano-convex lens of equivalent power

Close-up view of a flat Fresnel lens shows concentric circles on the surface

The Fresnel lens reduces the amount of material required compared to a conventional lens by dividing the lens into a set of concentric annular sections. An ideal Fresnel lens would have infinitely many such sections. In each section, the overall thickness is decreased compared to an equivalent simple lens. This effectively divides the continuous surface of a standard lens into a set of surfaces of the same curvature, with stepwise discontinuities between them.

In some lenses, the curved surfaces are replaced with flat surfaces, with a different angle in each section. Such a lens can be regarded as an array of prisms arranged in a circular fashion, with steeper prisms on the edges, and a flat or slightly convex center. In the first (and largest) Fresnel lenses, each section was actually a separate prism. 'Single-piece' Fresnel lenses were later produced, being used for automobile headlamps, brake, parking, and turn signal lenses, and so on. In modern times, computer-controlled milling equipment (CNC) might be used to manufacture more complex lenses.

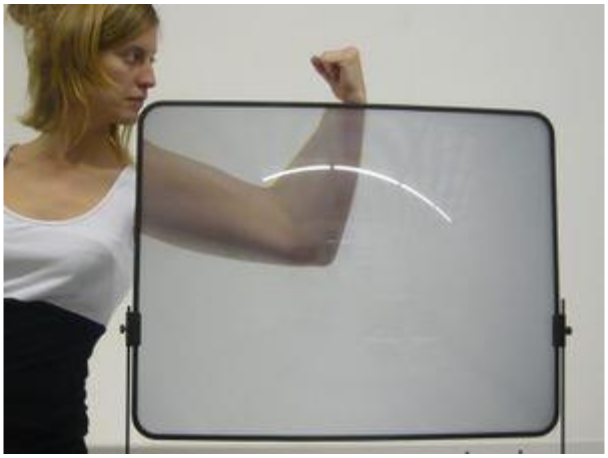
Fresnel lens design allows a substantial reduction in thickness (and thus mass and volume of material), at the expense of reducing the imaging quality of the lens, which is why precise imaging applications such as photography usually still use larger conventional lenses.

Fresnel lenses are usually made of glass or plastic; their size varies from large (old historical lighthouses, meter size) to medium (book-reading aids, OHP viewgraph projectors) to small (TLR/SLR camera screens, micro-optics). In many cases they are very thin and flat, almost flexible, with thicknesses in the 1 to 5 mm (0.039 to 0.197 in) range.

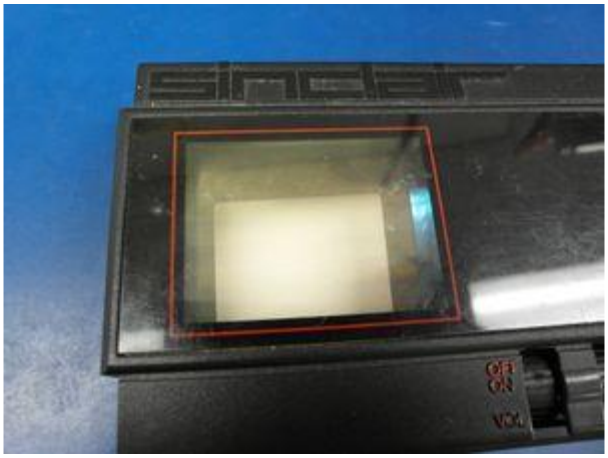
Modern Fresnel lenses usually consist of all refractive elements. However many of the lighthouses have both refracting and reflecting elements, as shown in the photographs and diagram. That is, the outer elements are sections of reflectors while the inner elements are sections of refractive lenses. Total internal reflection was often used to avoid the light loss in reflection from a silvered mirror.

USES

Imaging



A plastic Fresnel lens sold as a TV-screen enlarging device



The Fresnel lens used in the Sinclair FTV1 portable CRT TV, which enlarges the vertical aspect of the display only

Fresnel lenses are used as simple hand-held magnifiers. They are also used to correct several visual disorders, including ocular-motility disorders such as strabismus. Fresnel lenses have been used to increase the visual size of CRT displays in pocket televisions, notably the Sinclair TV80. They are also used in traffic lights.

Fresnel lenses are used in left-hand-drive European lorries entering the UK and Republic of Ireland (and vice versa, right-hand-drive Irish and British trucks entering mainland Europe) to overcome the blind spots caused by the driver operating the lorry while sitting on the wrong side of the cab relative to the side of the road the car is on. They attach to the passenger-side window.

Another automobile application of a Fresnel lens is a rear view enhancer, as the wide view angle of a lens attached to the rear window permits examining the scene behind a vehicle, particularly a tall or bluff-tailed one, more effectively than a rear-view mirror alone.

Multi-focal Fresnel lenses are also used as a part of retina identification cameras, where they provide multiple in- and out-of-focus images of a fixation target inside the camera. For virtually all users, at least one of the images will be in focus, thus allowing correct eye alignment.

Fresnel lenses have also been used in the field of popular entertainment. The British rock artist Peter Gabriel made use of them in his early solo live performances to magnify the size of his head, in contrast to the rest of his body, for dramatic and comic effect. In the Terry Gilliam film *Brazil*, plastic Fresnel screens appear ostensibly as magnifiers for the small CRT monitors used throughout the offices of the Ministry of Information. However, they occasionally appear between the actors and the camera, distorting the scale and composition of the scene to humorous effect. The Pixar movie Wall-E features a fresnel lens in the scenes where the protagonist watches the musical magnified on an iPod.

Photography

Canon and Nikon have used Fresnel lenses to reduce the size of telephoto lenses. Photographic lenses that include Fresnel elements can be much shorter than corresponding conventional lens design. Nikon calls their technology *Phase Fresnel*.

The Polaroid SX-70 camera used a Fresnel reflector as part of its viewing system.

View and large format cameras can utilize a Fresnel lens in conjunction with the ground glass, to increase the perceived brightness of the image projected by a lens onto the ground glass, thus aiding in adjusting focus and composition.

Illumination

Inchkeith lighthouse lens and drive mechanism

High-quality glass Fresnel lenses were used in lighthouses, where they were considered state of the art in the late 19th and through the middle of the 20th centuries; most are now retired from service. Lighthouse Fresnel lens systems typically include extra annular prismatic elements, arrayed in faceted domes above and below the central planar Fresnel, in order to catch all light emitted from the light source. The light path through these elements can include an internal reflection, rather than the simple refraction in the planar Fresnel element. These lenses conferred many practical benefits upon the designers, builders, and users of lighthouses and their illumination. Among other things, smaller lenses could fit into more compact spaces. Greater light transmission over longer distances, and varied patterns, made it possible to triangulate a position.

Automobiles: Perhaps the most widespread use of Fresnel lenses, for a time, occurred in automobile headlamps, where they can shape the roughly parallel beam from the parabolic reflector to meet requirements for dipped and main-beam patterns, often both in the same headlamp unit (such as the European H4 design). For reasons of cost, weight, and impact resistance, newer cars have dispensed with glass Fresnel lenses, using multifaceted reflectors with plain polycarbonate lenses. However, Fresnel lenses continue in wide use in automobile tail, marker, and backup lights.

Glass Fresnel lenses also are used in lighting instruments for theatre and motion pictures; such instruments are often called simply *Fresnels*. The entire instrument consists of a metal housing, a reflector, a lamp assembly, and a Fresnel lens. Many Fresnel instruments allow the lamp to be moved relative to the lens' focal point, to increase or decrease the size of the light beam. As a result, they are very flexible, and can often produce a beam as narrow as 7° or as wide as 70°. The Fresnel lens produces a very soft-edged beam, so is often used as a wash light. A holder in front of the lens can hold a colored plastic film (*gel*) to tint the light or wire screens or frosted plastic to diffuse it. The Fresnel lens is useful in the making of motion pictures not only because of its ability to focus the beam brighter than a typical lens, but also because the light is a relatively consistent intensity across the entire width of the beam of light.

Aircraft carriers and naval air stations typically use Fresnel lenses in their optical landing systems. The "meatball" light aids the pilot in maintaining proper glide slope for the landing. In the center are amber and red lights composed of Fresnel lenses. Although the lights are always on, the angle of the lens from the pilot's point of view determines the color and position of the visible light. If the lights appear above the green horizontal bar, the pilot is too high. If it is below, the pilot is too low, and if the lights are red, the pilot is very low.

The Fresnel lens has seen applications for enhancing passenger reading lights on Airbus aircraft: in a dark cabin, the focused beam of light does not dazzle neighboring passengers.

Projection

The use of Fresnel lenses for image projection reduces image quality, so they tend to occur only where quality is not critical or where the bulk of a solid lens would be prohibitive. Cheap Fresnel lenses can be stamped or molded of transparent plastic and are used in overhead projectors and projection televisions.

Fresnel lenses of different focal lengths (one collimator, and one collector) are used in commercial and DIY projection. The collimator lens has the lower focal length and is placed closer to the light source, and the collector lens, which focuses the light into the triplet lens, is placed after the projection image (an active matrix LCD panel in LCD projectors). Fresnel lenses are also used as collimators in overhead projectors.

Solar power

Since plastic Fresnel lenses can be made larger than glass lenses, as well as being much cheaper and lighter, they are used to concentrate sunlight for heating in solar cookers, in solar forges, and in solar collectors used to heat water for domestic use. They can also be used to generate steam or to power a Stirling engine.

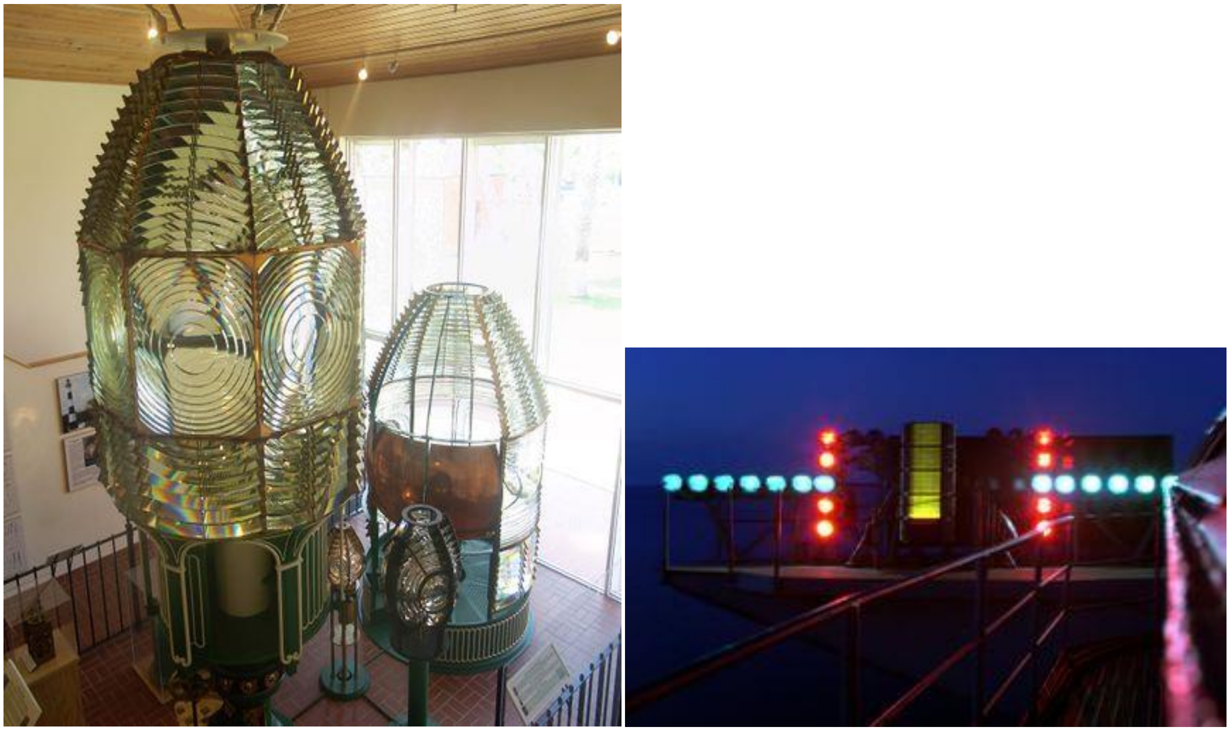
Fresnel lenses can concentrate sunlight onto solar cells with a ratio of almost 500:1. This allows the active solar-cell surface to be reduced, lowering cost and allowing the use of more efficient cells that would otherwise be too expensive. In the early 21st century, Fresnel reflectors began to be used in concentrating solar power (CSP) plants to concentrate solar energy. One application was to preheat water at the coal-fired Liddell Power Station, in Hunter Valley Australia.

Fresnel lenses can be used to sinter sand, allowing 3D printing in glass.

In fiction

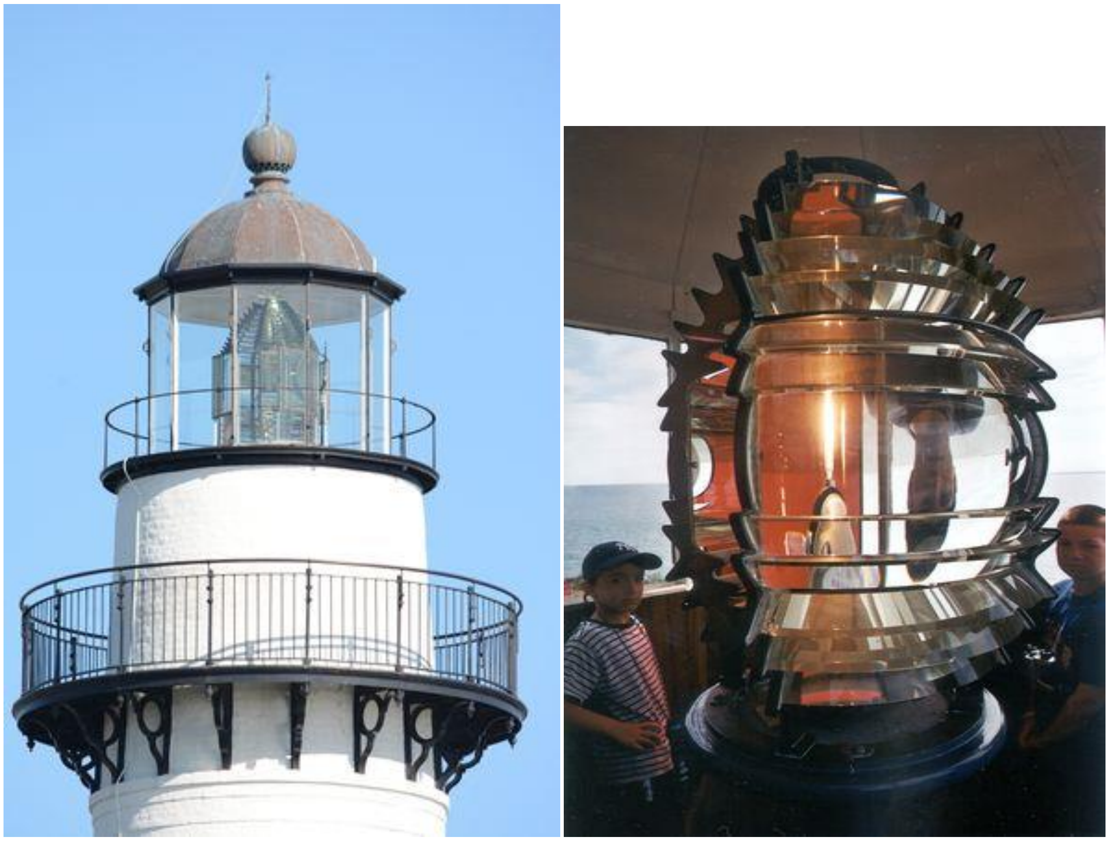
The English children's fantasy television series *Shadows* features an episode "The Other Window", in which a scientist places a Fresnel lens on a window of his home, and his children and his mother are able to see visions of their ancestors in previous centuries in it.

Images for kids



1st-order lens on the left/Optical Landing System on US Navy aircraft carrier USS *Dwight D. Eisenhower*

Close-up of a second-order lens/Third-order lens (Sekizaki Lighthouse, Oita, Japan)



Third-order lens at St. Simons Island Light

Technology

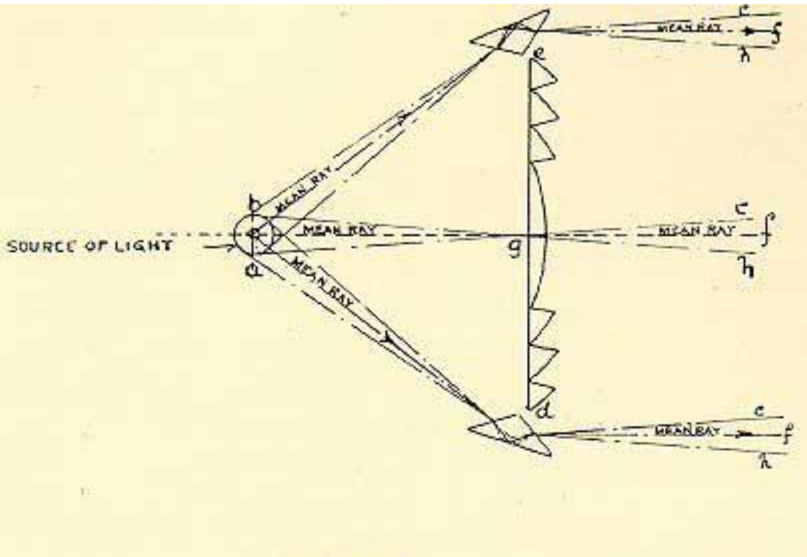


FIG. 8

Lighthouse Apparatus are divided into various "orders," as follows, according to their Focal Distance, that is, half the diameter of the Apparatus on the Focal Plane:

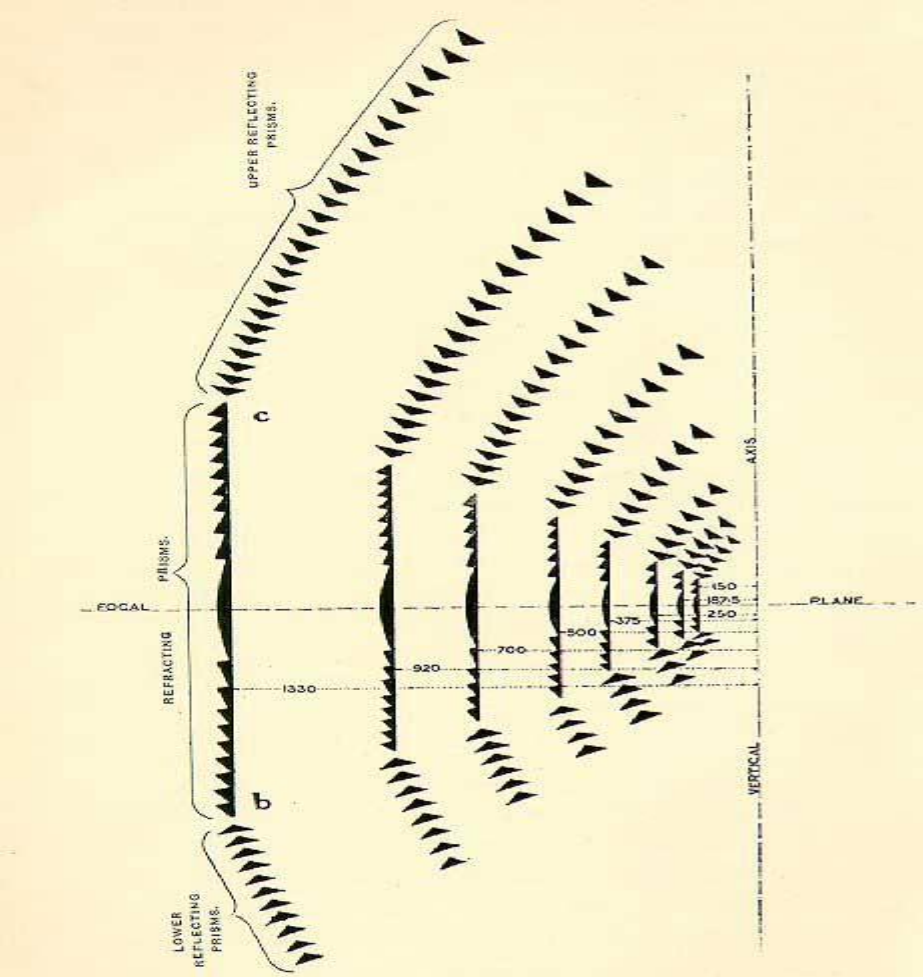


FIG. 4

Fresnel's lighthouse lenses originally fell into six orders based on their focal length. The order of a Fresnel lens is approximately the dioptre or optical power of the lens. The dioptre is the reciprocal of the focal length of the lens in meters. A Fresnel lens with a focal length of 50 cm or 0.5 m would be classified as a third order lens.

Sir James Timmins Chance. CHANCE BROTHERS & CO Birmingham UK.

From 1851, Chance Brothers became a major lighthouse engineering company, producing optical components, machinery, and other equipment for lighthouses around the world.

Sir James Timmins Chance pioneered placing lighthouse lamps inside a cage surrounded by fresnel lenses so as to increase the available light output; these cages, known as optics, revolutionised lighthouse design. Another important innovation from Chance Brothers was the introduction of rotating optics, allowing adjacent lighthouses to be distinguished from each other by the number of times per revolution that the light flashes.

LIGHTHOUSE OPTICAL LENSES

Lighthouse optical lenses were commonly made from 2 distinct glass groups, crown and flint glass, crown glass commonly used up to the 19 century.

Crown Glass

Crown glass is a type of optical glass used in lenses and other optical components. It has relatively low refractive index (≈1.52) and low dispersion. Crown glass is produced from alkali-lime (RCH) silicates containing approximately 10% potassium oxide and is one of the earliest low dispersion glasses.

As well as the specific material named crown glass, there are other optical glasses with similar properties that are also called crown glasses. Generally, this is any glass with Abbe numbers in the range 50 to 85. For example, the borosilicate glass is an extremely common crown glass, used in precision lenses. Borosilicates contain about 10% boric oxide, have good optical and mechanical characteristics, and are resistant to chemical and environmental damage. Other additives used in crown glasses include zinc oxide, phosphorus pentoxide, barium oxide, fluorite and lanthanum oxide.

Flint Glass

Flint glass is optical glass that has relatively high refractive index and low Abbe number. Flint glasses are arbitrarily defined as having an Abbe number of 50 to 55 or less. The currently known flint glasses have refractive indices ranging between 1.45 and 2.00.

The term flint derives from the flint nodules found in the chalk deposits of southeast England that were used as a source of high purity silica by George Ravenscroft, circa 1662, to produce a potash lead glass that was the precursor to English lead crystal.

Gustaf Dalén

Buoys & Beacons

Buoys and beacons are used as an Aid to Navigation (AtoN) and to assist lighthouses. They are found along harbours, inlets, channels, reefs and piers as markers.

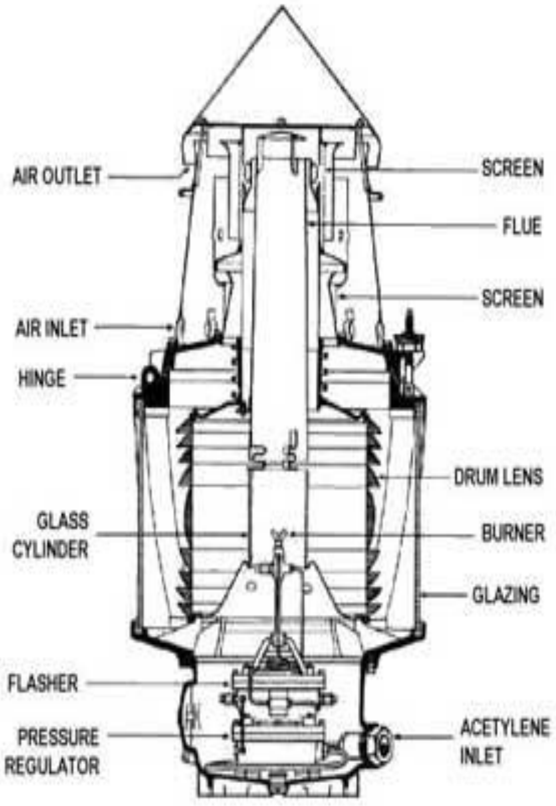
Various company made these buoys and beacons, the most well known were AGA and Chance Brothers. Other lesser known companies include Pintsch Bamag, Henry Lapaute, Joyce and Brandt.

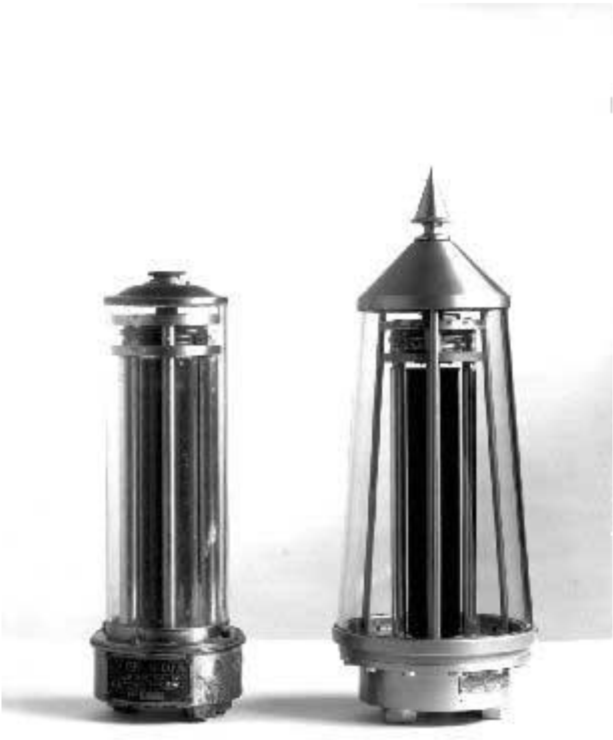
The AGA industrial company was founded in 1904. Initially AGA mainly focused on acetylene gas for railway lighting.

Soon the company employed inventive genius Gustaf Dalén as chief engineer and workshop manager whose inventions enabled AGA to grow rapidly.

It was the company’s inventions within lighthouse technology – the flashing beacon in 1905, the AGA compound in 1906, the sun valve and Dalén mixer in 1907 – which were to dictate the company's future.

By 1909 Dalén was president for the company. 1912 Gustaf Dalén was badly injured in an explosion which left him blind for life. He was still convalescing when the Swedish Royal Academy of Sciences awarded him the Nobel Prize in Physics for his “inventions of self-operating regulators, which in combination with gas accumulators can be used to light lighthouses and light buoys." He never regained his sight but he remained as the company's president for another 25 years, until his death 1937.





THE SUN VALVE

In 1907 Gustaf Dalén produced perhaps his most famous invention, the sun valve. This turns the beacon on and off using daylight. The first one was erected on Furuholmen’s lighthouse between Stockholm and Vaxholm. The design was so ingenious that many prominent contemporary engineers, including Thomas Alva Edison, doubted that the sun valve could work. The patent office in Berlin went so far as demand a special demonstration before it would approve the patent application.

The sun valve consists of a central, blackened, light absorbing metal rod surrounded by three gilt light-reflecting metal rods, all parallel with each other. In darkness all the rods are the same temperature and length. When dawn breaks the blackened rod absorbs light energy and acquires a slightly higher temperature than the shiny rods. The blackened rod becomes very slightly longer than the shiny ones triggering a device which cuts off the gas and switches off the lighthouse light.

When dusk falls, the blackened rod contracts, the gas valve opens and a small pilot flame lights the beacon. Combined with the flashing apparatus, the sun valve saves 94% of the gas compared with having the beacon alight all the time.

Light characteristics

See also: Light characteristic

In any of these designs an observer, rather than seeing a continuous weak light, sees a brighter light during short time intervals. These instants of bright light are arranged to create a light characteristic or pattern specific to a lighthouse. For example, the Scheveningen Lighthouse flashes are alternately 2.5 and 7.5 seconds. Some lights have sectors of a particular color (usually formed by colored panes in the lantern) to distinguish safe water areas from dangerous shoals. Modern lighthouses often have unique reflectors or Racon transponders so the radar signature of the light is also unique.

Building

Design

For effectiveness, the lamp must be high enough to be seen before the danger is reached by a mariner.

Where dangerous shoals are located far off a flat sandy beach, the prototypical tall masonry coastal lighthouse is constructed to assist the navigator making a landfall after an ocean crossing. Often these are cylindrical to reduce the effect of wind on a tall structure, such as Cape May Light. Smaller versions of this design are often used as harbor lights to mark the entrance into a harbor, such as New London Harbor Light.

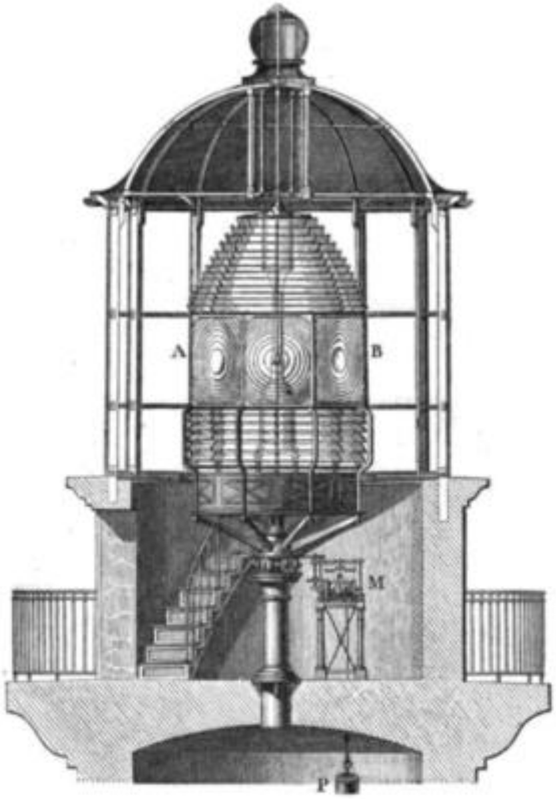
Where a tall cliff exists, a smaller structure may be placed on top such as at Horton Point Light. Sometimes, such a location can be too high, for example along the west coast of the United States, where frequent low clouds can obscure the light. In these cases, lighthouses are placed below clifftop to ensure that they can still be seen at the surface during periods of fog or low clouds, as at Point Reyes Lighthouse. Another victim of fog was the Old Point Loma lighthouse, which was replaced in 1891 with a lower lighthouse, New Point Loma lighthouse.

As technology advanced, prefabricated skeletal iron or steel structures tended to be used for lighthouses constructed in the 20th century. These often have a narrow cylindrical core surrounded by an open lattice work bracing, such as Finns Point Range Light.

Sometimes a lighthouse needs to be constructed in the water itself. Wave-washed lighthouses are masonry structures constructed to withstand water impact, such as Eddystone Lighthouse in Britain and the St. George Reef Light off California. In shallower bays, Screw-pile lighthouse ironwork structures are screwed into the seabed and a low wooden structure is placed above the open framework, such as Thomas Point Shoal Lighthouse. As screw piles can be disrupted by ice, steel caisson lighthouses such as Orient Point Light are used in cold climates. Orient Long Beach Bar Light (Bug Light) is a blend of a screw pile light that was converted to a caisson light because of the threat of ice damage.

In waters too deep for a conventional structure, a lightship might be used instead of a lighthouse, such as the former lightship *Columbia*. Most of these have now been replaced by fixed light platforms (such as Ambrose Light) similar to those used for offshore oil exploration.

Components



Lighthouse lantern room from mid-1800s

While lighthouse buildings differ depending on the location and purpose, they tend to have common components.

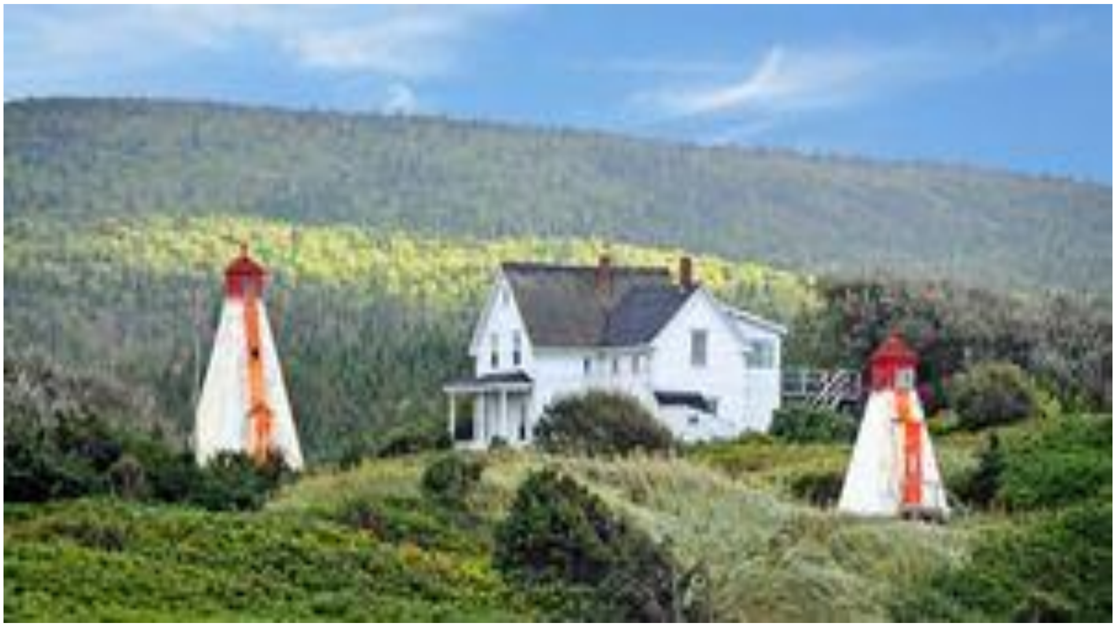
A light station comprises the lighthouse tower and all outbuildings, such as the keeper's living quarters, fuel house, boathouse, and fog-signaling building. The Lighthouse itself consists of a tower structure supporting the lantern room where the light operates.

The lantern room is the glassed-in housing at the top of a lighthouse tower containing the lamp and lens. Its glass storm panes are supported by metal *Astragal* bars running vertically or diagonally. At the top of the lantern room is a stormproof ventilator designed to remove the smoke of the lamps and the heat that builds in the glass enclosure. A lightning rod and grounding system connected to the metal cupola roof provides a safe conduit for any lightning strikes.

Immediately beneath the lantern room is usually a Watch Room or Service Room where fuel and other supplies were kept and where the keeper prepared the lanterns for the night and often stood watch. The clockworks (for rotating the lenses) were also located there. On a lighthouse tower, an open platform called the gallery is often located outside the watch room (called the Main Gallery) or Lantern Room (Lantern Gallery). This was mainly used for cleaning the outside of the windows of the Lantern Room.

Lighthouses near to each other that are similar in shape are often painted in a unique pattern so they can easily be recognized during daylight, a marking known as a daymark. The black and white barber pole spiral pattern of Cape Hatteras Lighthouse is one example. Race Rocks Light in western Canada is painted in horizontal black and white bands to stand out against the horizon.

Range lights



Range Lights in Margaree Harbour, Nova Scotia. When the vessel is on the correct course, the two lights line up above one another.

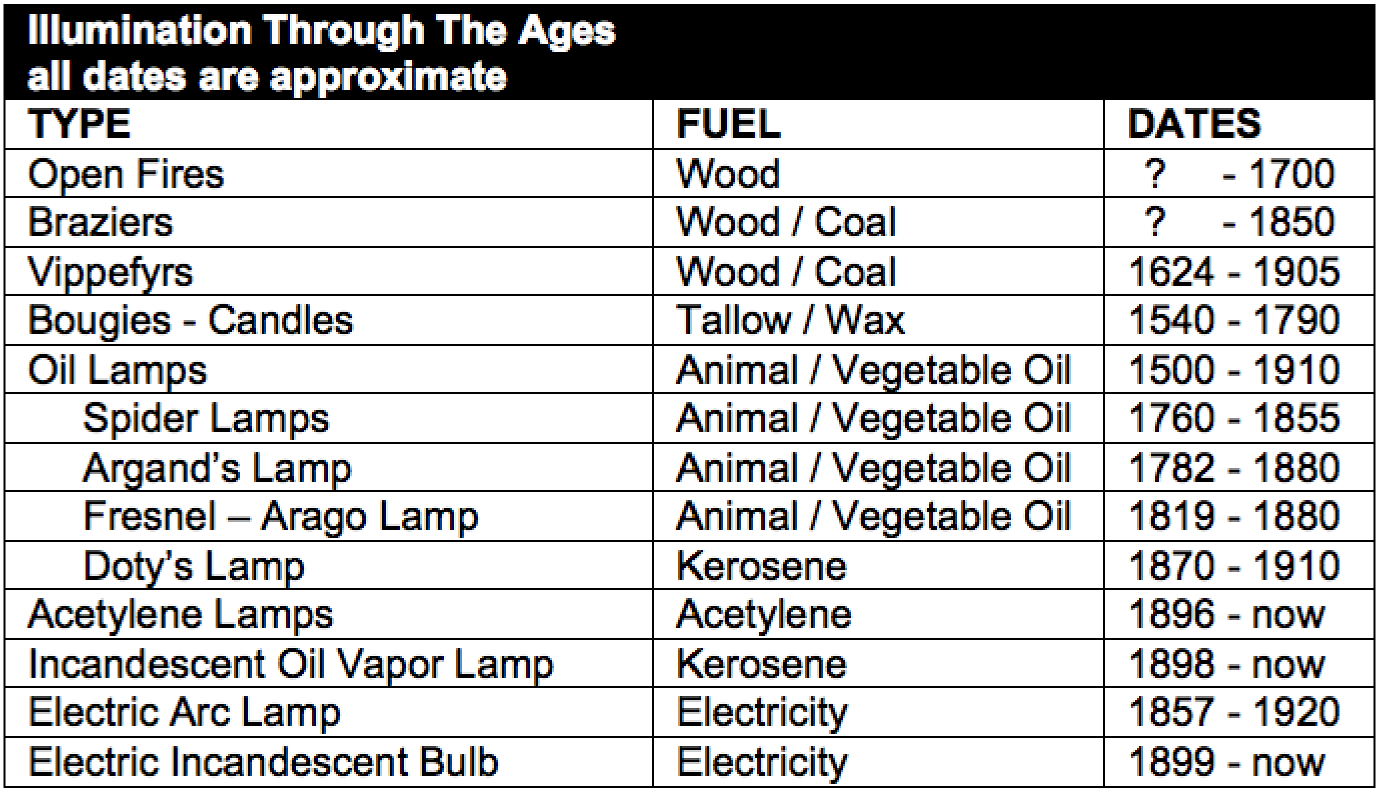
Aligning two fixed points on land provides a navigator with a line of position called a range in the U.S. and a transit in Britain. Ranges can be used to precisely align a vessel within a narrow channel such as in a river. With landmarks of a range illuminated with a set of fixed lighthouses, nighttime navigation is possible.

Such paired lighthouses are called range lights in the U.S. and leading lights in the United Kingdom. The closer light is referred to as the beacon or front range; the furthest away is called the rear range. The rear range light is almost always taller than the front.

When the vessel is on the correct course, the two lights line up vertically. But when the observer is out of position, the difference in alignment indicates the proper direction of travel to correct the course.

Lighthouse Lamps Through Time by Thomas Tag

The ingenuity of man is truly amazing and this can easily be seen in the odd collection of techniques used for the illumination of lighthouses across the centuries. Lighthouse illumination began with simple wood fires and progressed through generations of other methods. Even the oil lamp began in simplicity and evolved into a machine with multiple wicks, clockwork oil pumps, specialized chimneys, hydraulic, pneumatic, and other variants. This story will take you through the history of illumination methods in lighthouses.



Illumination Through The Ages
all dates are approximate

TYPE	FUEL	DATES
Open Fires	Wood	? - 1700
Braziers	Wood / Coal	? - 1850
Vippefyrs	Wood / Coal	1624 - 1905
Bougies - Candles	Tallow / Wax	1540 - 1790
Oil Lamps	Animal / Vegetable Oil	1500 - 1910
Spider Lamps	Animal / Vegetable Oil	1760 - 1855
Argand's Lamp	Animal / Vegetable Oil	1782 - 1880
Fresnel – Arago Lamp	Animal / Vegetable Oil	1819 - 1880
Doty's Lamp	Kerosene	1870 - 1910
Acetylene Lamps	Acetylene	1896 - now
Incandescent Oil Vapor Lamp	Kerosene	1898 - now
Electric Arc Lamp	Electricity	1857 - 1920
Electric Incandescent Bulb	Electricity	1899 - now

Braziers

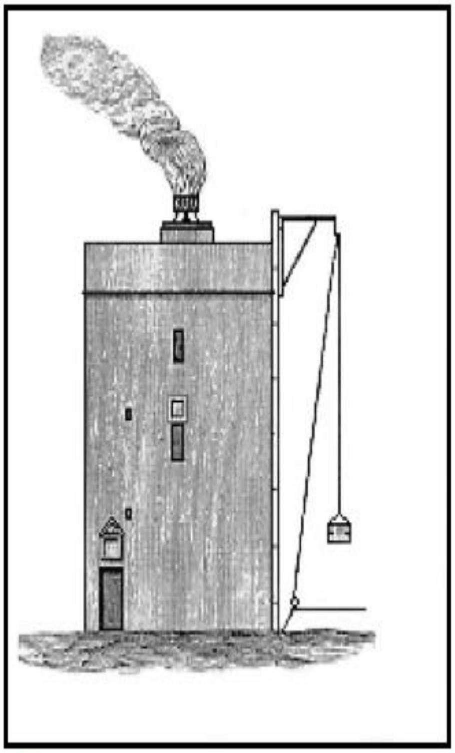
COAL AND WOOD FIRES

The early mariner's warning lights consisted chiefly of open fires and later of fire beacons maintained on a grate or in an iron basket known as a brazier and shown from an elevated location or platform near the coast. They were often unreliable because of the variability between burning well, with lots of flame and therefore light, or burning poorly with little flame or much smoke obscuring the light. These beacons were maintained both by public and private enterprises. Patents were granted to certain individuals for the upkeep of beacons in England and Scotland. While in other countries, the governments accepted the total responsibility for building and maintaining the warning lights.

The first English lighthouse to use mined coal was Dungeness in 1616, and its coal-fired brazier consumed as many as 400 tons of coal per year. The quality of the light from brazier coal fires varied considerably with weather conditions. When a strong wind blew off the land toward the sea, the light on the seaside became quite bright, but when the wind came from off the water the side of the fire facing the sea would be quite dark, while the land side of the fire was bright, yet useless. This was a great problem, because it was precisely when the wind was blowing toward shore that the most brilliant light was needed, and the most danger to shipping was present.

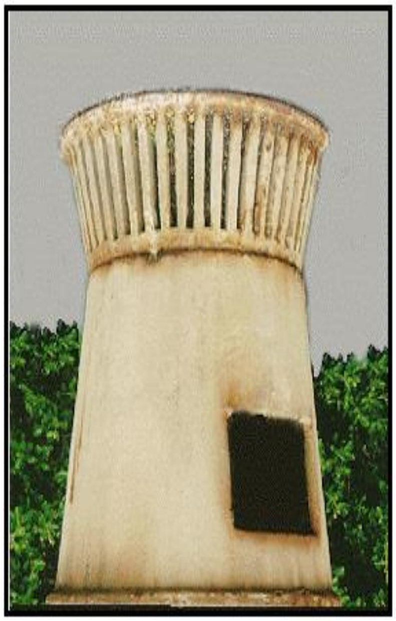
At first these fires were burnt in the open, but later they were enclosed by a lantern provided with a ventilating flue in an attempt to carry away the smoke, which would form around the fire and frequently obscure the light. The lanterns were not always a success as the glazing became blackened, and in a number of cases they were removed. One of the earliest known coal-fire towers to be fitted with a lantern is to be found on the island of St. Agnes in the Isles of Scilly in England. It was built in 1680, and the brazier, in which the fire was burnt, is still in existence.

The Isle of May, in Scotland, was the location of an old lighthouse established in the year 1636. The original lighthouse consisted of a stone tower with a large brazier for the burning of coal at its' top. The coal was set alight each night and burned an average of a little over one ton of coal per night. The coal fire was exhibited every night from the lighthouse's opening in 1636 until February 4, 1816, when it was replaced by a new lighthouse using reflectors, each with an Argand style oil lamp. A primitive block and tackle was used to raise the coal to the brazier on the top of the tower by the three men who were assigned to the stoking of the fire. The old coal fires survived in England until 1822, and there were examples of such lights in service in the Baltic region until 1850.

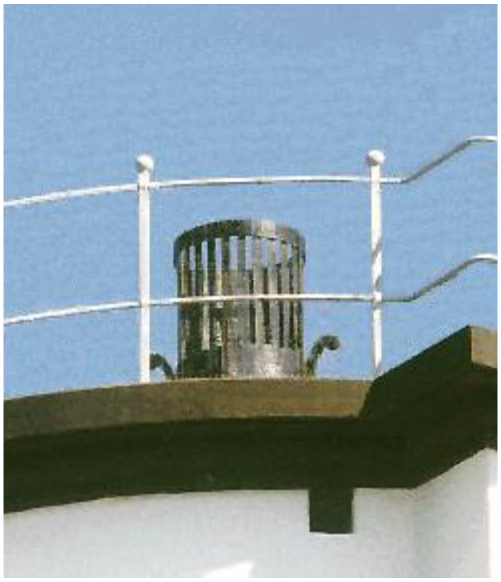


(Drawing by author from old manuscript)
Old Isle of May Lighthouse.

(Photo from Author's collection)
Replica of an Early English Coal Brazier.



(Photo from Authors Collection)
St. Agnes Brazier ca. 1680 - 1809

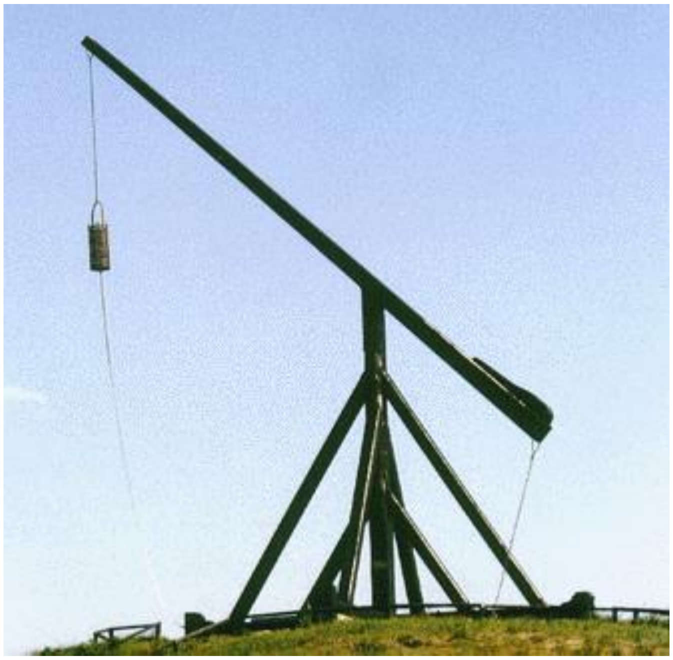


(Photo from the Egbert Koch collection) **Brazier Fire Basket at the Skagen 'Hvide Fyr' Light. (ca. 1700)**

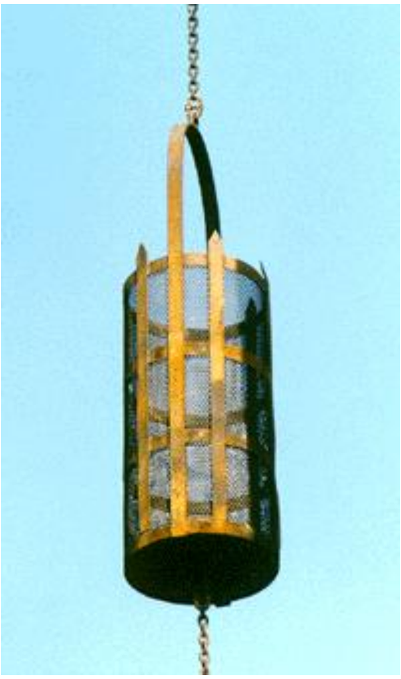
VIPPEFYRS

In Denmark, Jens Pedersen Groves designed the Vippefyr in 1624, which utilized the lever principle to raise a fire into the air. He drove one end of a large square beam in the ground strengthened by several additional diagonal supports. Pivoted from the main beam was a balanced cross member, or lever. One end of the lever was attached by a chain to a large fire basket, while the other end was weighted to facilitate raising the fire basket some 14 to 30 feet into the air. The long end of the lever, with the fire basket, was usually covered with metal sheathing as a protection against fire. The fire basket could be lowered when the keepers needed to fill it with coal or wood or to stoke the fire. It was then raised again to show the signal. One of the last Vippefyrs to be used was as a small local light on the island of Gothland, in Denmark, in 1905.

In England a similar device known as the Swape was used. The coal or wood fire was made in a metal basket, which could be easily tended on the ground and then elevated by means of the Swape, or fire lever. The great English Civil Engineer, John Smeaton visited Spurn Point in 1767 and decided to use a Swape there. He designed an improved version of the Swape with a small umbrella to protect the control rope from falling cinders.



(Photo from the Egbert Koch collection) **The Vippefyr at Skagen Denmark. (ca. 1624)**

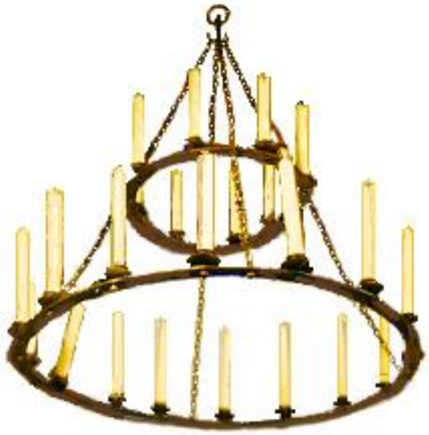


(Photo from the Egbert Koch collection) **The Vippefyr's Fire Basket.**

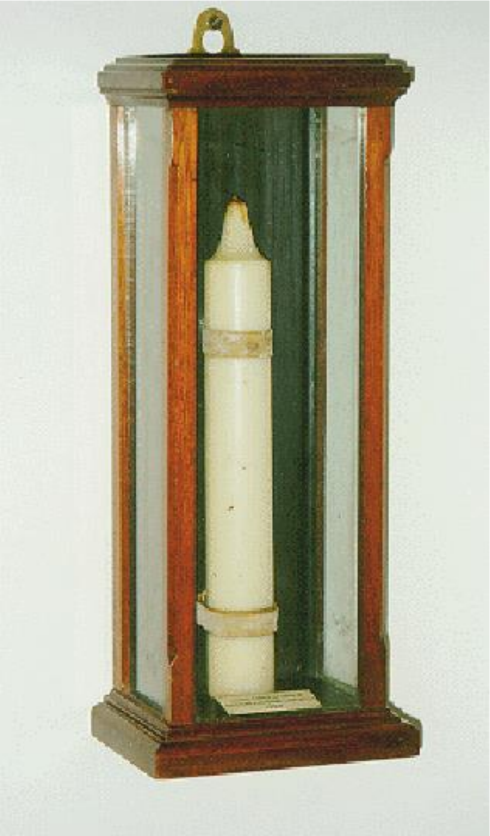
Bougies and Candles

The first use of candles consisted of a simple lantern shown at a window by a hermit or a monk. It was only when the enclosed lantern room was developed that the use of candles was made possible for use in lighthouses. The light from individual candles was rather feeble however, when a number of candles were placed in a candelabrum, and protected from the wind by the lantern windows, the light was a significant improvement over that from the coal fires. Candles were used in many lighthouses in Europe in the 1500s and were first used in England at the North Shields lighthouse in 1540. In France the name for candles was Bougies, which were made from tallow and used in their earliest lighthouses. The first lighthouse illumination in America came also from tallow candles, which were used for several years in the first Boston lighthouse and in most other early 18th century American lights. The keepers usually made the candles on site, because commercially produced candles were virtually nonexistent. Wax candles were used, but were very expensive; tallow candles were cheaper, but smoky and bad smelling.

In the original Winstanley Eddystone lighthouse, 60 one-pound candles were used when it was first lit in 1698. In Smeaton's Eddystone lighthouse in 1759, the first light exhibited was from 24 candles, which produced a rather feeble light, although, it is said that the light could be seen by telescope from Plymouth Hoe, 12 miles away. The candles Smeaton used at Eddystone weighted 2/5 of a pound each and the 24 candles had to be replaced about once every 3 hours.



A replica of the candelabra originally installed in the Eddystone lighthouse. (1759)



An actual candle from the Eddystone lighthouse. (1759)

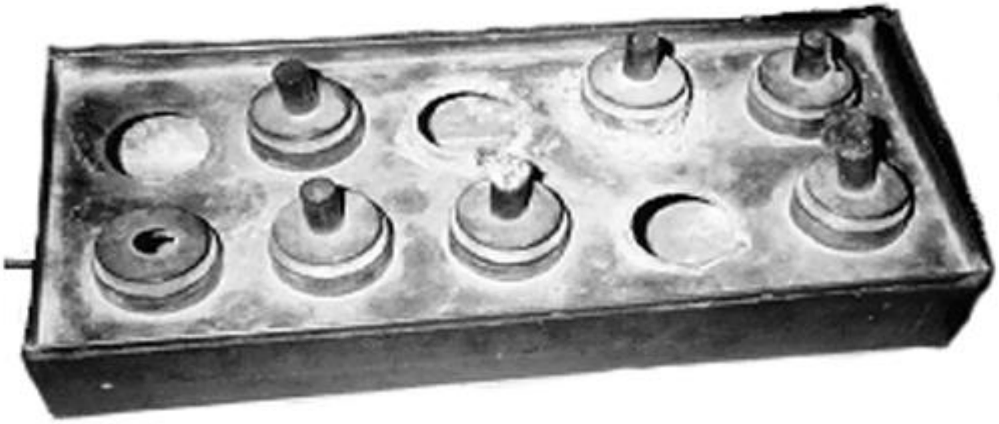
Oil Lamps Overview

The Cresset was one of the earliest forms of oil lamp used in a lighthouse. It consisted of a bowl hollowed out of stone, which was filled with fish oil, with one or more small rope wicks. As the years passed, several other types of oil lamps began to be used. The lamps, were usually made by local artisans, and began to be used as early as 1500. At this time, there were no standard types of lamps in use; however, most lamps had solid-rope wicks made of loosely braided cotton and a rather small common oil reservoir that fed one or more wicks. These lamps initially burned fish oil, seal oil, and later whale oil. They used no chimneys or reflectors, and produced a very poor light with much smoke and acrid fumes. Small tin lamps were tried, but failed due to their lack of a sufficient oil supply and poor flame qualities. The solid wicks had very poor combustion of the oil on the wick, producing large quantities of smoke. Later improvements were made by flattening the wicks to allow the ambient air to better reach both sides. While this produced a better flame, some smoke and soot was still produced, and portions of the oil remained unconsumed by the flame.

SPIDER LAMPS

By the 1760s, a form of Spider Lamp known as the Pan Lamp replaced the other early oil lamps in some lighthouses. The Sandy Hook light, in New Jersey, built in 1764, is reported to have used two Pan Lamps with a total of 48 oil blazes, hung from the lantern room ceiling by chains. Pan Lamps came in several forms. There were circular and rectangular pans, and a donut shaped Pan Lamp was used in the early lightships. Pan Lamps with a circular form were also known as Compass Lamps.

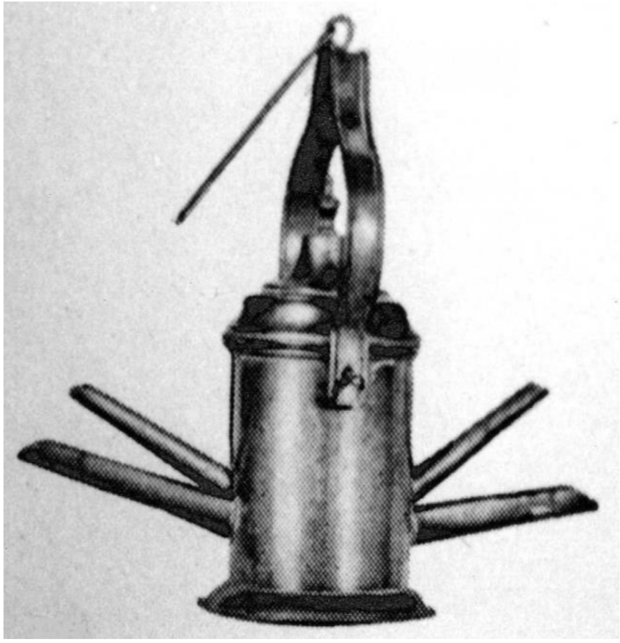
The Pan Lamp solved the problem of a limited oil supply and could operate for twelve or more hours on one fill of oil. The Pan Lamp had multiple rope wicks. The number of wicks varied from two too as many as twenty-four, with eight to ten wicks being very common. The Pan Lamp produced more light than the other early oil lamps because individual large diameter wicks were placed nearly side by side across the surface of the metal pan, and the flames could all be seen at the same time. Its main drawbacks were its relatively low light output, its massive consumption of oil, and the smoke and fumes produced within the lantern room, which at times became almost intolerable.



A typical Pan Lamp with ten ‘blazes.’ (ca.1760)

Pan Lamps were used for a very long time. The early light lists show a Compass Lamp with 8 wicks still in use at the Vermilion beacon light, in Ohio, in 1849. Compass Pan Lamps were the only style of lamp in use on American lightships until the mid 1850s.

The Bucket Lamp, another form of Spider Lamp, had been available for many years and began to be used in lighthouses in the latter part of the 1700s, mainly in the smaller lighthouses, beacon, and pier-head lights. The Bucket Lamp was made of sheet metal and was cylindrical in shape, with two or four spouts protruding from its sides. Each spout carried a large diameter rope wick that extended down inside the body of the lamp into the oil. Below each spout was a similarly shaped drip catcher. The Bucket Lamp held up to an eight-quart oil supply and could operate for twelve or more hours on one fill of oil. Its main drawbacks were still the very poor light produced, the smoke and fumes, and the problem that some of the flames were hidden from view behind the bucket, when it was viewed from specific directions. The Cape Henry light used this style lamp in 1792 and burned fish oil probably from Herring. The use of Bucket Lamps lasted a long time and four were recorded as being in use in 1845, at the Cunningham Creek Beacon light in Ohio.



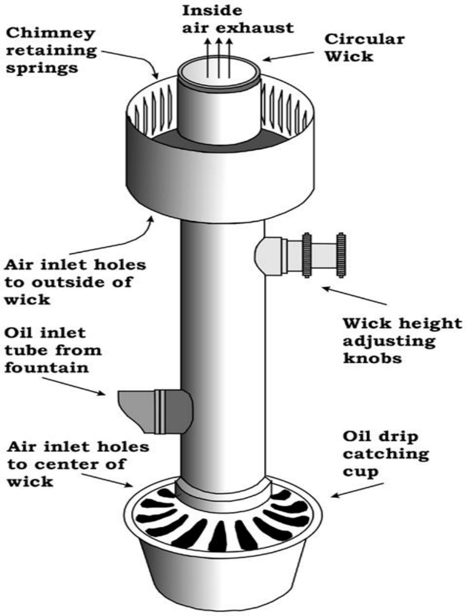
A typical Bucket Lamp with two wicks. (ca. 1780)

Fountain Lamps

Fountain lamps use a closed container of fuel with a small valve at its lower end. The valve is set at a height slightly below the top of the wick in the lamp burner. As fuel is burned, the valve in the fountain opens slightly to admit additional oil into the tube going to the burner. The fountain lamp maintains the fuel at a constant level at the burner. Fountain lamps function through capillary attraction and do not overflow the wicks.

ARGAND’S LAMP

In 1782, François-Pierre Ami Argand (1750-1803), a Swiss born physicist living in France, invented the double draft burner, which became known as the Argand oil lamp. Argand’s design used two thin metal tubes with one set inside the other. The wick was placed between these tubes and was thus formed into a long hollow cylinder. Air was allowed to enter the center of the wick through holes placed in the oil drip-cup attached to the bottom of the wick tubes. Air was also allowed to enter around the outside of the outer wick tube, through holes in the bottom of the chimney holder. Argand’s design provided much more oxygen to the flame, more efficient fuel combustion, and a much brighter light. Argand also invented the use of a chimney, which helped to provide additional airflow over the wick and protected the flame from outside air currents, which could make it flicker.

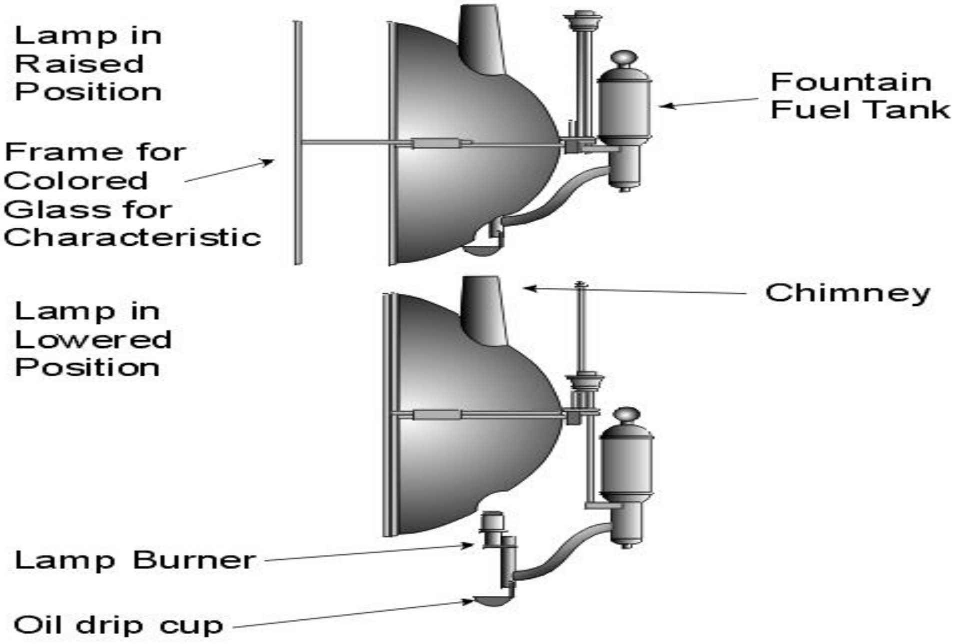

Inside air exhaust
Chimney retaining springs
Circular Wick
Air inlet holes to outside of wick
Wick height adjusting knobs
Oil inlet tube from fountain
Air inlet holes to center of wick
Oil drip catching cup

(Drawing by Author from a Lighthouse Board Drawing) **A typical Argand Lamp Burner. (1782)**

In 1787, another Frenchman, Monsieur Lange, invented the constricted chimney, which Argand quickly added to his design. The constricted chimney forced the outside air closer to the flame. This action further improved the combustion of the fuel, giving a still brighter flame, which was measured at about 7 candlepower.

ROBERT STEVENSON'S LAMP

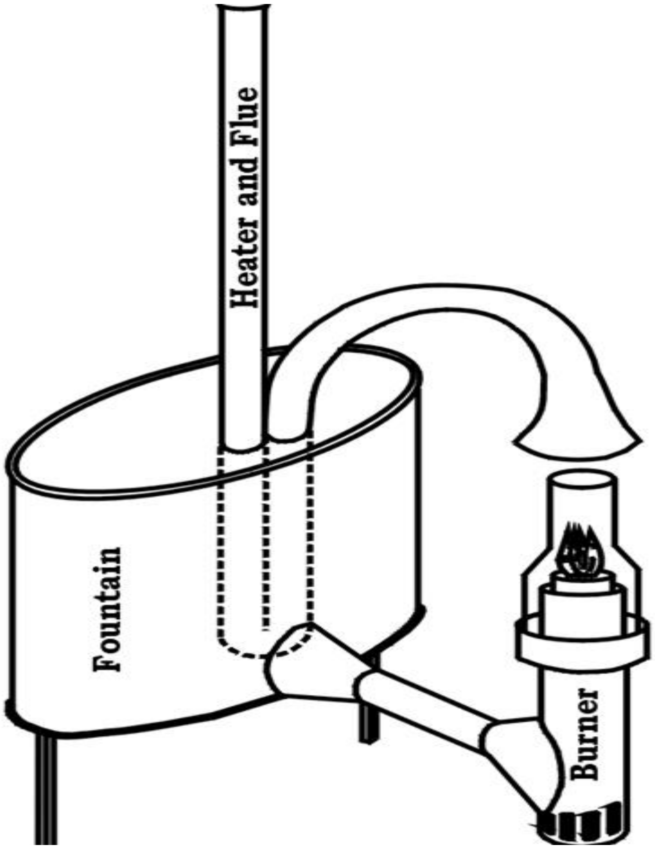
From 1803 to 1810, Robert Stevenson worked to improve the design of Scotland's copper parabolic reflectors and lamps. He chose an improved Argand lamp with a fountain fuel tank set in a true parabolic reflector with a heavy cladding of silver. The fountain fuel tank held 24 ounces of fuel. By 1809, he had succeeded in developing a design where the lamp was able to be released from the focus of the reflector by turning a locking ring, that let the lamp assembly slide down, allowing easy wick replacement or trimming, and allowing easy polishing of the inside of the reflector. When the work was completed, the keeper raised the lamp back into its preset position, in the reflector's focus, and locked it with the ring. Stevenson's new lamps were first installed in the Bell Rock lighthouse in 1811.



(Drawing by Author from Drawing in Lighthouse Illumination 1859) **Robert Stevenson's Retractable Lamp with Reflector. (1811)**

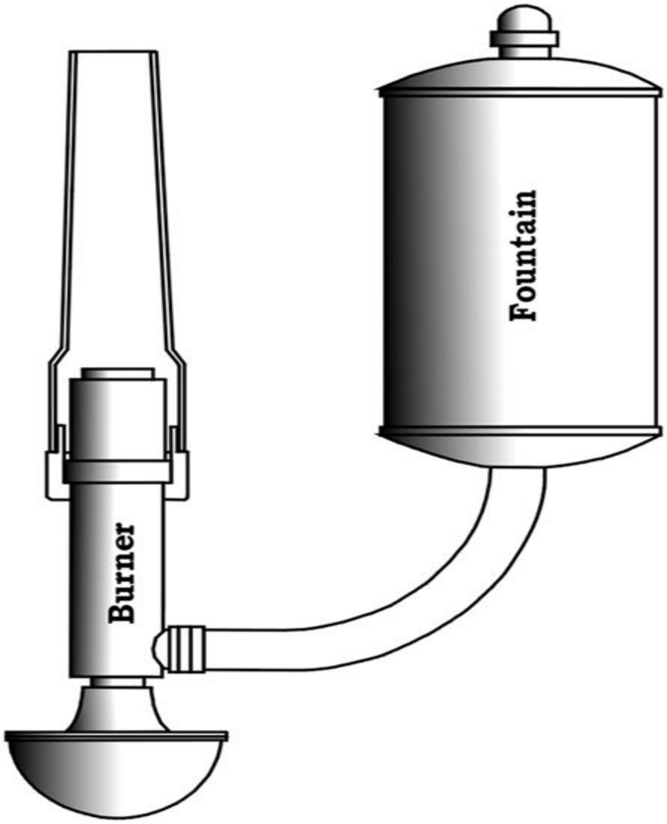
WINSLOW LEWIS' LAMPS

Winslow Lewis, an American ship captain, created a crude lamp design, but he succeeded in impressing the government through actual trials of the lamp's performance and low oil consumption, which were held at the Boston lighthouse. In 1812, U.S. Government paid Lewis over $ 20,000 for his invention.



(Drawing by Author from patent drawing) **Winslow Lewis Lamp Patent 2901-X. (1818)**

The lamp in Lewis' design was a rough copy of an Argand style lamp with a three-quarter inch burner. The original lamp also used a short glass chimney and a simple woven-cotton lamp wick, which was poorly made, and resulted in inefficient fuel usage. Nearly all of the American lighthouses from 1812 to 1840 used the Winslow Lewis reflector and lamp design, and most continued to use the design until about 1858.



(Drawing by Author from Patent Drawing) **Winslow Lewis / Benjamin Hemmenway Lamp. (1844)**

Oil and Kerosene Lamps for use in Fresnel Lenses

A number of styles of lamps were used within the Fresnel lenses. They varied both by the operating principals of their construction and by the order, or size, of the Fresnel lens in which they were placed. The main styles of lamps were as follows:

Capillary Lamps

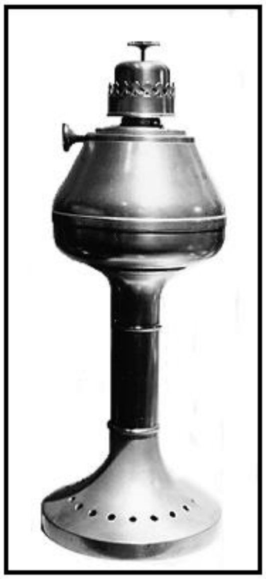
Capillary lamps are based on the principle of capillary attraction where the fuel is raised to the flame by the wick itself. In these lamps the fuel is stored below the burner and the fibers of the wick soak up the fuel and raise it from the fuel reservoir to the top of the wick through capillary action within the fibers. These lamps were used in the fourth-order and smaller lenses.

FUNCK’S IMPROVED FOURTH-ORDER LAMP (1888)

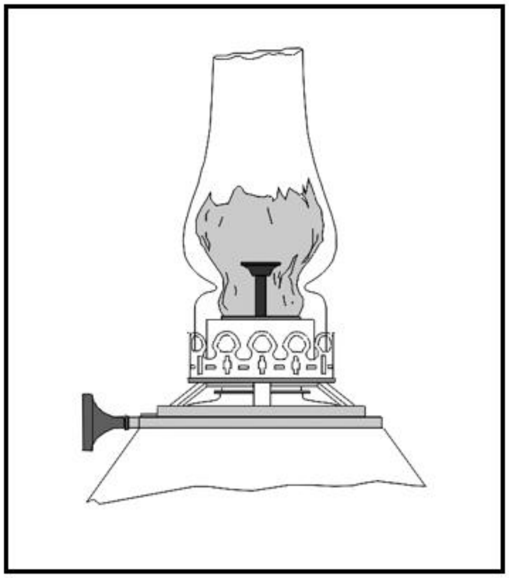
In 1888, Joseph Funck was able to dramatically improve the lamps used in the fourth-order lenses in America. Funck redesigned the old fourth-order lamp and produced the 'improved-fourth-order lamp,' which had a new flame spreader and a number of airflow adjustments.

THE FUNCK-HEAP LAMP (1892)

In the smaller lighthouses a lamp called the Funck-Heap lamp was introduced in 1892. It was a standard Argand lamp with a single one and one-eighth-inch wick. There was a flame-spreading button in the center of the flame that got red-hot and helped to keep the flame a constant size and shape. The feeding of the wick was accomplished by a screw thread on the wick carrying tube. The Funck-Heap lamp became the standard lamp used in all fourth-order lenses in the American Lighthouse Service and was refitted into all of the lighthouses using a fourth-order lens as quickly as it could be manufactured. The same design with slight variations in the flame spreader and chimney was developed for the fifth and sixth-order lamps.



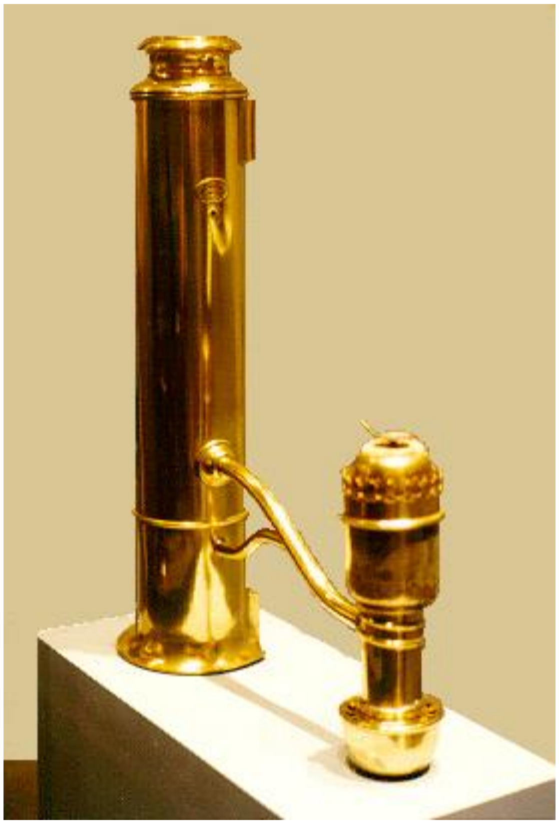
(Photograph from Author's collection)
The Funck – Heap fourth-order lamp.



(Drawing by Author from Annual Report of the Lighthouse Board)
The Improved Funck – Heap fifth and sixth-order burner.

FUNCK'S CONSTANT LEVEL FOUNTAIN LAMP (1876)

The constant level lamp was used in what was known as a projector light. Projector lights were used as range lights using the constant level lamp backed by a parabolic reflector. Constant level lamps were also used with a single small Fresnel bulls-eye lens in front of the lamp as range lights.



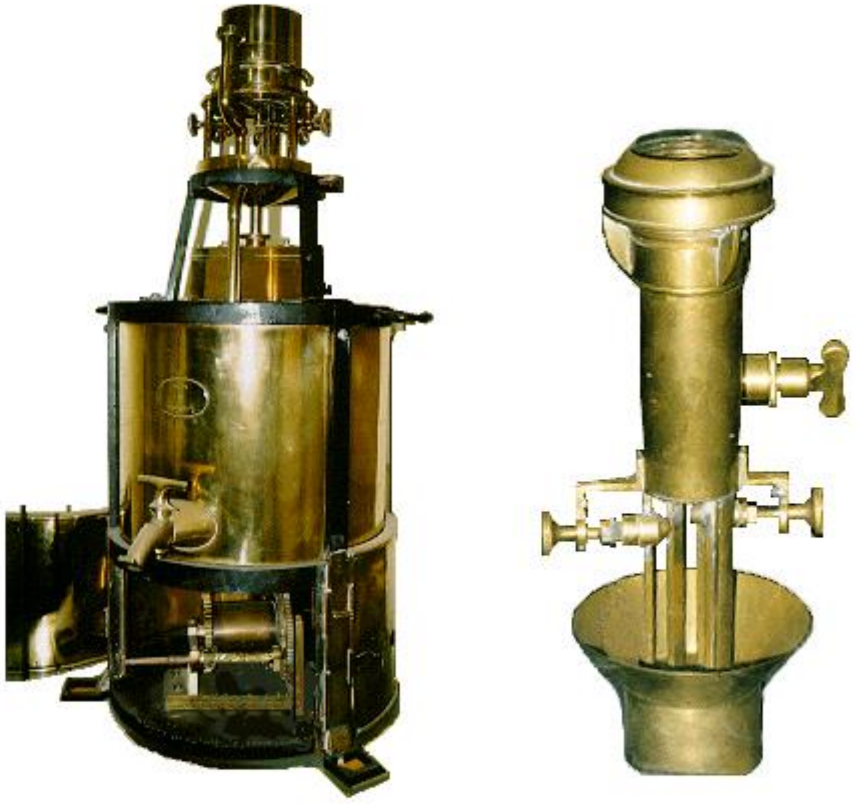
American Constant Level Lamp.

Mechanical Overflow Lamps

FRESNEL-ARAGO CLOCKWORK-CONCENTRIC-WICK LAMPS (1819)

Augustin Fresnel and François Arago used the ideas of Count Rumford and the Guyton de Morveau to design new Argand style lamps, and made a series of trials of lamps with various numbers of concentric wicks, in late 1819. It was found that a standard Argand lamp, even with multiple concentric wicks, would not perform as required, because the multiple wicks caused such great heat that the burner would melt and the wicks would quickly char. After many trials it was found that the Argand style lamp invented by Monsieur Bertrand Carcel in 1800 could be used with multiple concentric wicks.

The Carcel lamp had a double-piston-mechanical pump operated by clockwork that forced excess oil through a tube to the wick, overflowing the wick and cooling the entire burner. By December 1819, Fresnel and Arago had created a multiple-concentric-wick lamp using the Carcel cooling principal and the first triple-wick burner was operational in their laboratory. Within a few months, they also developed a quadruple-wick burner and proposed its use within the first, first-order lens that was manufactured.



An early Fresnel-Arago Lamp with a Carcel pump clockwork shown in the base. (1823) On right- French Two Wick Lamp. (1840)

THE LEPAUTE ESCAPEMENT LAMP (CA.1830)

In the 1830s, Augustin Henry-Lepaute developed the escapement lamp using metal pistons instead of the leather ones used in the original Fresnel-Arago lamps, and two groups of dual alternating pumps versus the two simple pumps in the original Fresnel-Arago lamp. It was run by clockwork through a toothed wheel known as an escapement, which allowed the pump drive mechanism to operate in only one direction. However, many technical difficulties remained in the Lepaute escapement lamp and it was not used except in trials until about 1845, when Monsieur Wagner improved its design.

THE WAGNER PUMP LAMP (1845)

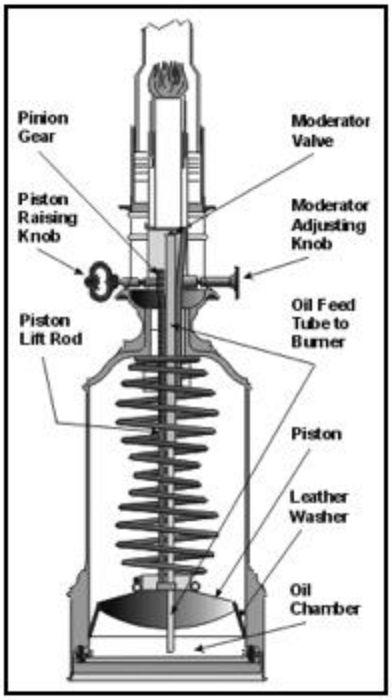
In 1845, Wagner, who was an engineer working for Augustin's brother Leonor Fresnel, improved the design of Lepaute's escapement lamp. His design significantly strengthened the pump drive mechanism and simplified its operation. He also added a simple screw to each pump, designed to regulate the flow of the oil to the burner by reducing the opening left for the passage of oil.

FRANCHOT'S SPRING OPERATED MODERATOR LAMP (1836)

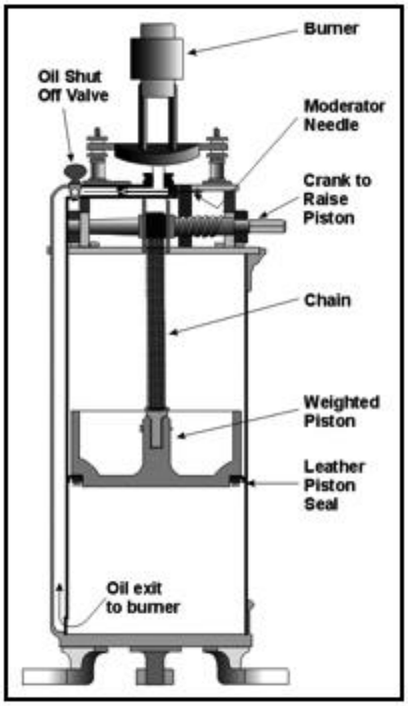
In 1836, Monsieur Franchot invented the Moderator lamp where a spiral spring operated piston made oil flow to the wicks through a constricted valve known as the moderator. These lamps were used in most fixed lenses in France, and in America when Fresnel lenses were first installed during the 1850s. However, they were not used in American lighthouses after about 1865.

The machinery placed in the reservoir of the lamp was formed by a spiral spring attached to a lightweight piston. The piston was made from a sheet-iron disk, fitted with a leather washer, and connected to a tube, which fed the burner. A square rod with gear teeth was connected to the piston, which served to raise the piston and compress the spring. The lamp was wound by turning a key fixed at the top of the burner, which operated a pinion gear meshed with the teeth of the square rod. It was necessary to windup the lamp before it was first lit each night, and it was necessary to rewind it at the end of about four hours' combustion. The piston, under pressure from the spring, pushed down on the oil, which forced it up the oil-feed tube to the moderator valve where it entered the base of the burner and fed the wick.

Franchot's moderator lamp was difficult to maintain because its spring drive was prone to getting stuck, its winding mechanism was easily jammed, and the moderator valve was difficult to properly maintain and provided only a very course fuel flow control.



(Drawing by Author from Lighthouse Board Drawing)
Franchot's Moderator Lamp. (1836)



(Drawing by Author from Lighthouse Board Drawing)
Lepaute's Moderator Lamp. (ca. 1845)

LEPAUTE'S MODERATOR LAMP (CA. 1845)

Augustin Henry-Lepaute began to redesign the moderator lamp in the early 1840s. He replaced the drive spring with a much heavier piston and replaced the wind up gearing with a chain drive that allowed the heavy piston to be easily raised with a crank. The moderator valve was replaced with an easily adjusted needle valve that moved automatically as the piston was lowered. These changes significantly improved the reliability of Lepaute's moderator lamp. However, the piston was still prone to become stuck and its leather seal wore out rather quickly. Most of the world's lighthouses converted to this lamp starting ca. 1860.

In this lamp the heavy piston pushed down on the oil only through its own weight and forced the oil up a tube on the side of the lamp body. The oil flowed up the tube into a chamber with a tiny hole located at the end toward the center of the lamp where the moderator needle was positioned. The moderator needle allowed a small and highly controlled flow of oil to pass into the burner at a steady rate.

Pneumatic Lamps

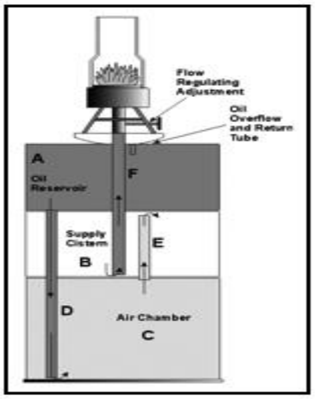
Pneumatic lamps operate through the use of air pressure to maintain a flow of oil or kerosene from the fuel reservoir below the burner up to the wicks.

THE WILKINS PNEUMATIC LAMP (1837)

This lamp is composed of a Reservoir ‘A’, which is filled with oil, a Supply Cistern ‘B’ filled with oil, and an Air Chamber ‘C’. There is a Tube ‘D,’ which passes from the bottom of the Reservoir ‘A’ to the Air Chamber ‘C’ through which the oil passes into the Air Chamber ‘C.’ A Tube ‘E’ from the top of the Air Chamber ‘C’ passes up into the Supply Cistern ‘B.’ The main Tube ‘F’ leading to the burner passes from the center of the Supply Cistern ‘B’ up through the Reservoir ‘A’ to the burner. The pressure of the oil from the Reservoir ‘A’ into the Air Chamber ‘C’ will force the air into the Supply Cistern ‘B’, and cause the oil to flow to the burner, so long as there is any oil in the Reservoir ‘A.’

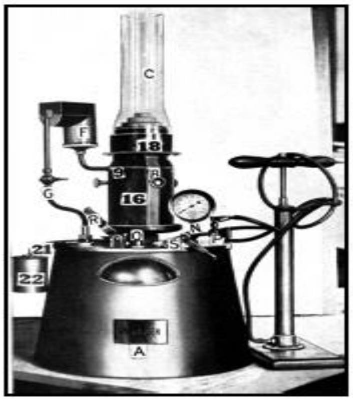
THE HEAP AIR-PRESSURE-PNEUMATIC LAMP (1899)

In 1899, David Heap began to study the significant maintenance problems with the hydraulic lamps then in use, and created the Air Pressure Lamp. This lamp used air pressure of 20 psi to push down on the kerosene and force it to flow to the lamp. The air pressure mechanism was very simple and very easy for the keeper to maintain. These lamps were first put into operation around 1900.



(Drawing by Author)

The Wilkins Pneumatic Lamp. (1837)



(Photograph from Instructions to Lighthouse Keepers)

The Air Pressure Lamp designed by D. P. Heap, which burned kerosene.

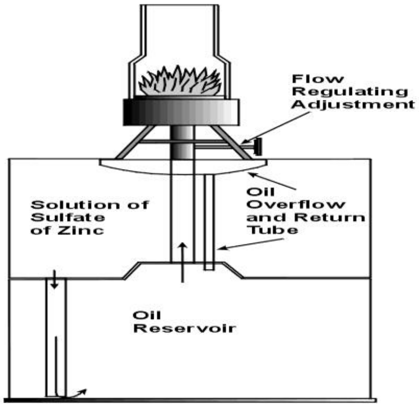
Hydrostatic Lamps

The Hydrostatic lamp was the invention of Peter Kier in 1787. It used the weight of a liquid slightly heavier than the oil, which would flow below the oil and force it up a tube to the wicks. It was not used in lighthouses until it was significantly improved through the efforts of the French chemist Thilorier many years later.

THILORIER'S HYDROSTATIC LAMP (CA. 1840)

Thilorier invented an improved Hydrostatic Lamp. This lamp required the use of dissolved sulfate of zinc and a test instrument called an 'Aerometer' to test the density of the dissolved sulfate of zinc. Thilorier used the zinc sulfate in solution as the heavy liquid, which flowed down a tube below the oil. The oil actually floated on the zinc sulfate and was forced up a tube to the burner and on to the wicks. Any excess oil that overflowed the burner was collected and returned to the top of the oil tank by an overflow and return tube. The hydrostatic lamp was used to replace the early unreliable, clockwork driven, mechanical lamps in fixed lights where a reliable fountain or hydraulic style lamp could not be used due to its fountain and piping producing unacceptable shadows within the lens. The Scottish lighthouse service chose this lamp for use in all of their fixed lenses starting in the mid 1840s.

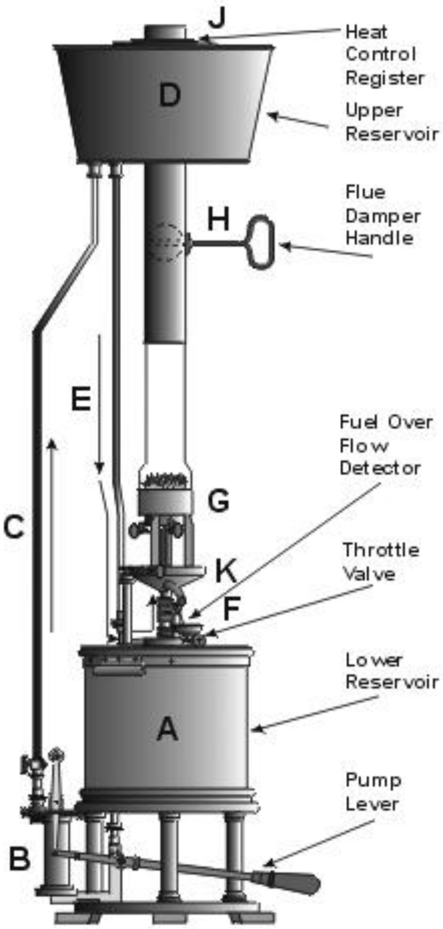
The main drawback to the hydrostatic lamp was that it functioned based on the relatively minor difference in the density (specific gravity) of the zinc sulfate vs. that of the oil. If the density of the zinc sulfate solution was not exactly correct the oil would not flow at all or would flow much too quickly.


Flow Regulating Adjustment
Solution of Sulfate of Zinc
Oil Overflow and Return Tube
Oil Reservoir

Thilorier's Hydrostatic Lamp. (ca. 1840)

Hydraulic Lamps

The hydraulic lamp was very similar to the fountain lamp and was used in all orders of lenses. It was based on gravity feed and consisted of a reservoir above the lens; another reservoir below the burner to contain the oil, which overflowed the burner; a pump to raise the oil to the upper reservoir, and the burner.



Hydraulic Lamp Overview.

GENERAL OPERATION OF A HYDRAULIC LAMP

At the start of each day, the keeper removed all of the oil in the Lower Reservoir 'A'. He would then fill the Lower Reservoir 'A' with clean fresh oil and close the Throttle Valve 'F.' The keeper then used the Pump Lever connected to Pump ‘B’ and pumped the fresh oil from the Lower Reservoir ‘A’ up through pipe ‘C’ into the Upper Reservoir ‘D,’ which held enough fresh oil for operation during the longest night of the year with some oil left over. The fresh oil filled the Upper Reservoir ‘D’ and then flowed down pipe ‘E’ to the Throttle Valve ‘F’ where it could flow no further. Note: in the hydraulic lamp designed by George Meade it was also possible to pump oil from a storage tank kept in the room below the lantern room instead of from the Lower Reservoir ‘A.’

In the evening the lamp was lit by opening the Throttle Valve ‘F,’ which allowed the oil to flow up a central tube passing through the oil Overflow Collector ‘K’ and into the Burner ‘G’ where it flowed through and over the wicks. The keeper lit the oil at the wicks and regulated the flow of oil by adjusting the Throttle Valve ‘F’ and by adjusting the height of the wicks by raising or lowering the wicks using the individual wick adjusting knobs on the Burner ‘G.’ The overflow of the oil passed over the concentric wicks and back down into the Overflow Collector ‘K’ and out a small tube into a Sensor Cup, which was a part of the Fuel Overflow Detector. An alarm bell was used with the lamps in Fresnel lens lights. It consisted of a lever that was pivoted like a teeter-totter. One end of the lever was raised and blocked the alarm mechanism. The other end of the lever held a small Sensor Cup with a small hole in its bottom. The Sensor Cup was located in the flow of the oil from the overflow of the burner. As long as oil overflowed the burner, the Sensor Cup was kept full of oil and the alarm lever was held in place. If the overflow of oil stopped, the Sensor Cup would cease to be filled and the oil within it would flow out through the small hole in its bottom. When this happened the alarm lever was no longer held in the up position and the end blocking the alarm mechanism lowered and the alarm would sound. The alarm usually consisted of a bell located in the tower or keeper’s quarters. After passing through the Sensor Cup the overflow oil was passed into the top of the Lower Reservoir ‘A’ through a small wire mesh strainer.

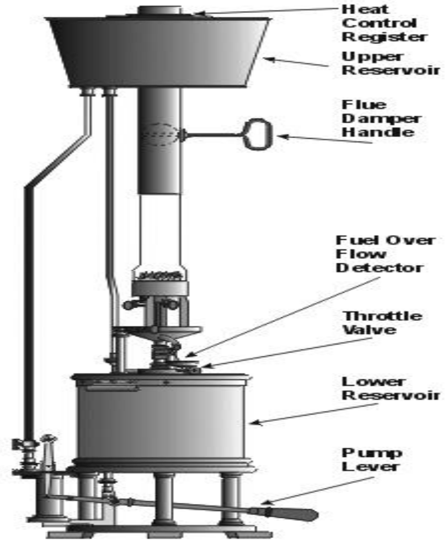
The air flow through the burner and chimney was regulated by hand adjusting the Flue Damper Handle ‘H.’ The Upper Reservoir ‘D’ had a cylindrical hole through its center. Through this hole a sheet-iron chimney passed down to the glass chimney. In the upper cover of the Upper Reservoir ‘D’ was a Heat Control Register ‘J’ that surrounded the sheet-iron chimney. When the register was open, the heated air passed through between the chimney and the reservoir, producing little effect upon the temperature of the oil. When it was closed, the heated air was obstructed and the oil was heated by it, so that in cold weather the oil was kept fluid enough to flow easily through the pipes.

THE WILKINS HYDRAULIC LAMP (CA. 1839)

This lamp was composed of a reservoir to hold the required quantity of oil for use during one night, a supply cistern, and a burner. From the bottom of the reservoir a tube connected to the supply cistern. In the end of this tube was a movable stop, to which was attached a hollow metallic ball, which served, as the oil in the cistern rose or fell, to regulate the flow of oil in the cistern, and to the burner. The oil was fed from the supply cistern through a tube from the bottom of the cistern to the burner, and up to the concentric wicks. The overflow of oil flowed into the overflow cistern.

MEADE'S HYDRAULIC LAMP (1853)

This lamp designed by George G. Meade, of the United States Corps of Topographical Engineers, and erected first at the Sand Key Lighthouse in Florida, and later at other locations.Meade's lamp was intended to take the place of the French mechanical lamps of the Fresnel-Arago and Lepaute patterns, and do away with the pumps and clockwork machinery. This lamp was previously described in the section 'General Operation of a Hydraulic Lamp.'



George G. Meade's Hydraulic Lamp. (1853)

FRANKLIN HYDRAULIC LAMP (1863) - FOR FOURTH, FIFTH, AND SIXTH ORDER LIGHTS

This lamp was designed by Captain William B. Franklin, United States Corps of Topographical Engineers, and Engineer Secretary of the Lighthouse Board. It consisted of four principal parts:

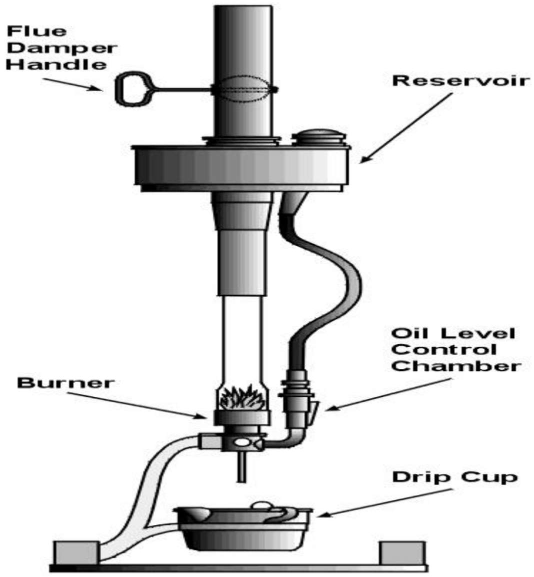
1. An airtight reservoir, with supply tube attached, resting on the upper ring of lens.

2. The burner, with reception tube and oil level control.

3. A bracket, with a drip-cup fastened to the bottom ring of the lens.

4. An oil level control air chamber opening into the reception tube.

Joseph Funck created an almost identical lamp for use with fourth, fifth and sixth order lenses in 1869 that also used his float valve design to replace the oil level control chamber of the Franklin hydraulic lamp.

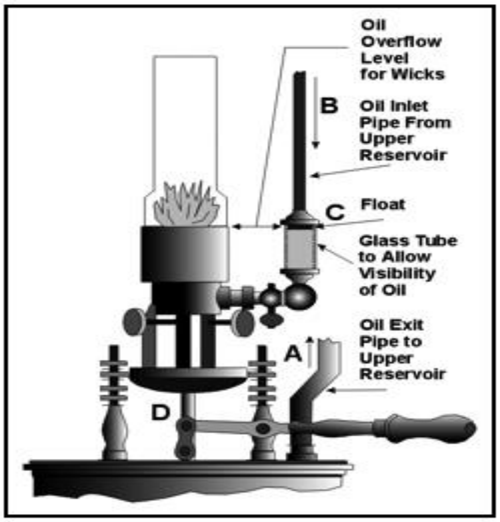


(Drawing by Author from Lighthouse Board Drawing) **Franklin's Hydraulic Lamp. (1863)**

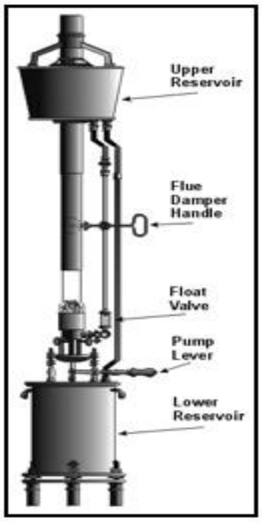
FUNCK’S HYDRAULIC-FLOAT LAMP (1869)

The major successor to the French mechanical lamp, in America, was a lamp designed by Mr. Joseph Funck, the foreman of the American Lighthouse Service workshops at the depot on Staten Island, New York.

Funck’s hydraulic float lamp had a pump, operated by hand, that raised the oil from the Lower Reservoir to the Upper Reservoir through Pipe ‘A.’ The oil then flowed down from the Upper Reservoir through Pipe ‘B’ into the Float Chamber. The Float ‘C’ was donut shaped and floated upon the surface of the oil in the glass chamber. In the center of the Float ‘C’ a small needle was fixed that pointed upward into a specially shaped restriction in the oil inlet Pipe ‘B’ and when the Float Chamber was full of oil, the needle in Float ‘C’ blocked further flow of oil from Pipe ‘B’ into the Float Chamber. The oil flowed to the wick after passing through the Float Chamber. As the oil flowed into and over the wicks, some of it being burned, the oil in the Float Chamber lowered and the Float ‘C’ lowered allowing more oil to enter the chamber. The Float ‘C’ was adjusted so as to rise and close the oil inlet as soon as the oil reached the proper height to just overflow the wick, thus maintaining the oil always at the same level. The overflow oil passed down through an Overflow Collector ‘D’ into the top of the Lower Reservoir.


Oil Overflow Level for Wicks
B
Oil Inlet Pipe From Upper Reservoir
C
Float
Glass Tube to Allow Visibility of Oil
A
Oil Exit Pipe to Upper Reservoir
D

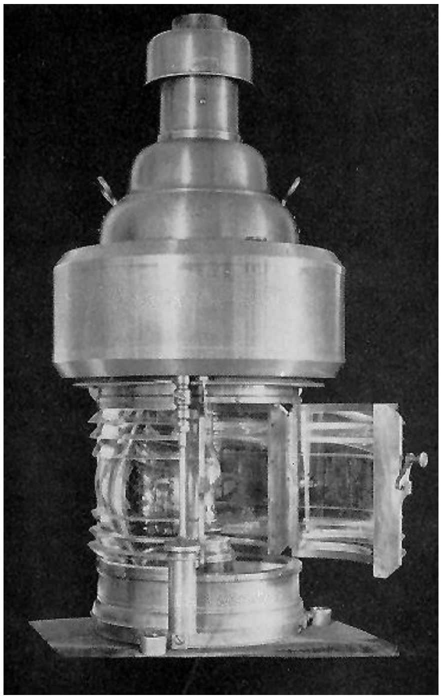
(Drawing by Author from Lighthouse Board Drawing)
Detail of the Float.



(Drawing by Author from Lighthouse Board drawing)
Joseph Funck’s Hydraulic Float Lamp. (1869)

FUNCK'S 8-DAY LAMP (1885)

In the early 1880s, there was a great need for lanterns that could be used as beacon lights on small piers and as post lamps, functioning as the warning lights for obstacles on the major inland rivers. The problem with the lamps, in use at the time, was their need for constant attention. In 1885, Joseph Funck developed the idea of adding a large circular tank for oil around the top of the lamp, giving it the capacity to operate for up to 8 days without attention. This design worked quite well, but the lamp itself was the old-fashioned flat wick variety and the lens was made of pressed glass of rather poor quality. The lamp was also susceptible to being blown out by strong winds.



The 5-Day Lens Lantern developed and improved by David Heap.

HEAP'S 5 AND 8-DAY LAMPS (1889)

In 1889, David Heap developed a further improved design for the American 8-day lantern and invented a new 5-day lantern. He described his thoughts in a report to the Lighthouse Board as follows:

"The eight-day tubular lens-lanterns having proved quite successful so far as maintaining a light without attention during that length of time, I believed that it would be advisable to apply the same principle to a lantern with cut-glass prisms, using a lamp with a circular burner and a chimney, and thus obtain a much more powerful light."

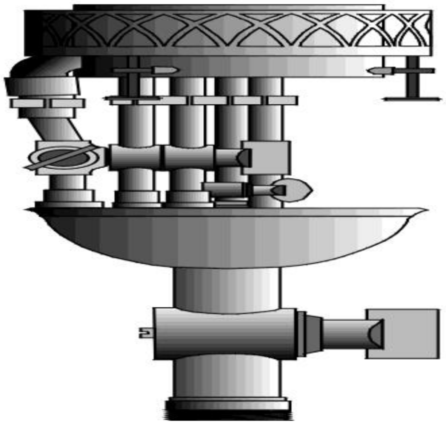
THE BENSON-LEE AUTOMATIC LAMP (1895)

By 1895 in Europe, the Benson–Lee automatic lamp was beginning to be used in beacons. It had special wicks that were tipped with carbon from tar and it required no trimming for four or five days of operation. It was chosen for all new installations in Scotland and acted like the American 8-day lamp. The Benson-Lee lamp replaced the earlier Trotter-Lindberg lamp developed in Sweden, which required significantly more technical knowledge to maintain.

Gas Burners

Monsieur Phillip Le Bond d'Hambersin was given a French patent for producing illuminating gas from wood in 1799, which was made by carbonizing wood in a closed retort. He called his invention the Thermo Lamp, which was first used in the Le Havre lighthouse in France that year.

Oil gas was first used at the Holyhead lighthouse in Wales in 1820 and from 1819 to 1827 Fresnel and Arago experimented with the use of gas burners for use within the Fresnel lenses, however, they chose to continue with the use of their multi-wick oil lamps. Also in 1823, Pintsch gas was tried at the South Foreland lighthouse in England. All of these early experiments with gas used simple tube or multiple tube burners.

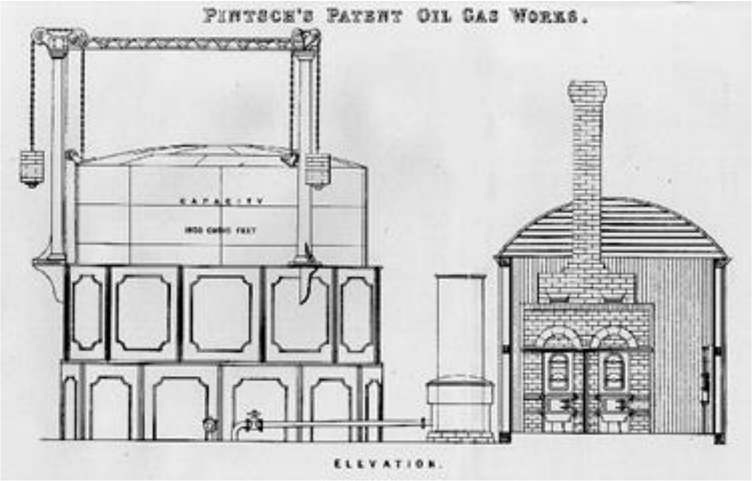


The Fresnel – Arago Gas Burner 1824.

A lighthouse built in 1829, known as the Barcelona light, and sometimes called the Portland light located on Lake Erie, was unique because of its fuel source. The nearby town of Fredonia, New York was the first site in North America to commercially use Natural gas, starting in 1821. The Barcelona lighthouse was located 18 miles west of Fredonia and for part of its life, it used a nearby 'spring' of Natural gas carried a distance of two miles in pipes to the tower to light its lamps. Unfortunately, the Natural gas gave out in 1838, and the gas lamps were removed.

An effort was made in 1841 to use another form of Wood gas known as Rosin gas at the Christina Creek light station, near Wilmington, Delaware. Rosin gas was made through the heating of pinesap (rosin) or pine logs in an enclosed retort. After about a year of trial, the effort at Christina Creek was abandoned as impractical.

Gas was later used in lighthouses in a number of countries. However, its production, delivery, and excessive heat restricted its use to a relatively small number of lighthouse locations. The major drawback was the need for the building and operation of a gas production plant next to each lighthouse where it was to be used.

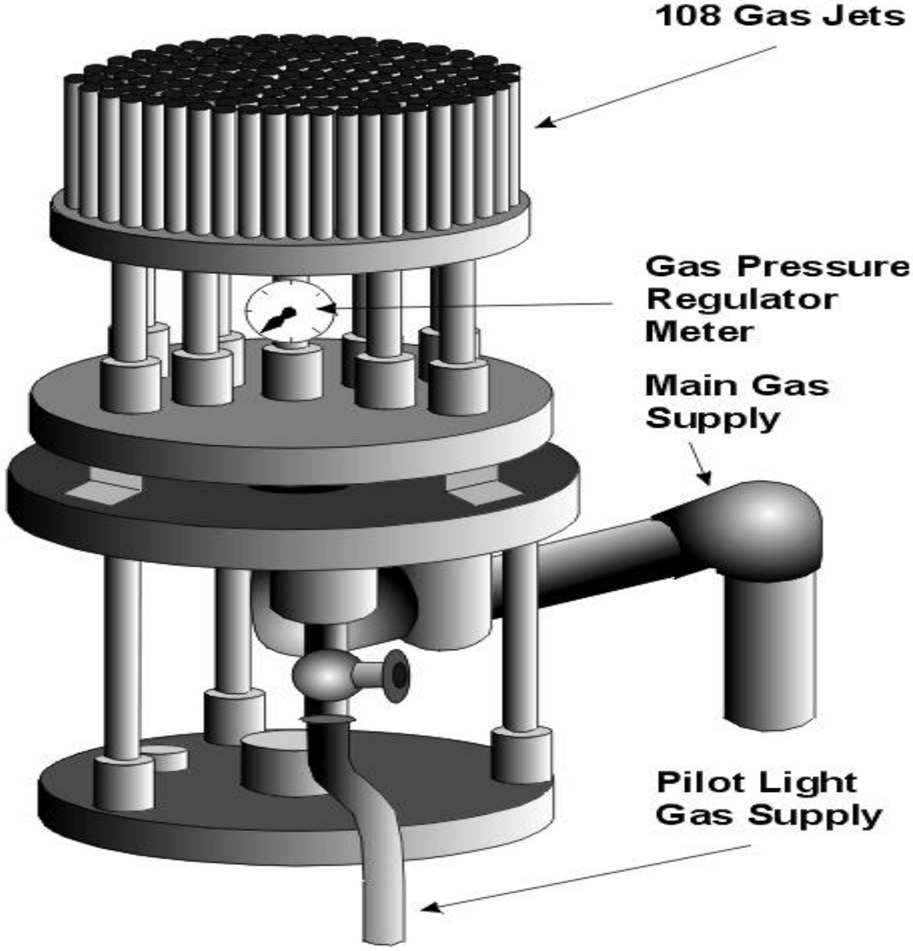


(Drawing from Trinity House Report on the Relative Merits of Electricity, Gas and Oil 1885)

A typical gas generation facility that had to be co-located with each lighthouse using gas.

WIGHAM'S COMPOSITE GAS BURNER (1868)

John R. Wigham developed many forms of lamps for use with coal gas in Ireland starting in 1865. His designs were the first that could be used reliably and which could be sized based on the size of the lens. Wigham's designs ranged from 28 to 108 gas jets and several still larger numbers of jets were experimented with. Wigham's gas lamps were used extensively in Ireland.



(Drawing by Author) **John R. Wigham's 108 Jet Composite Gas Burner. (1868)**

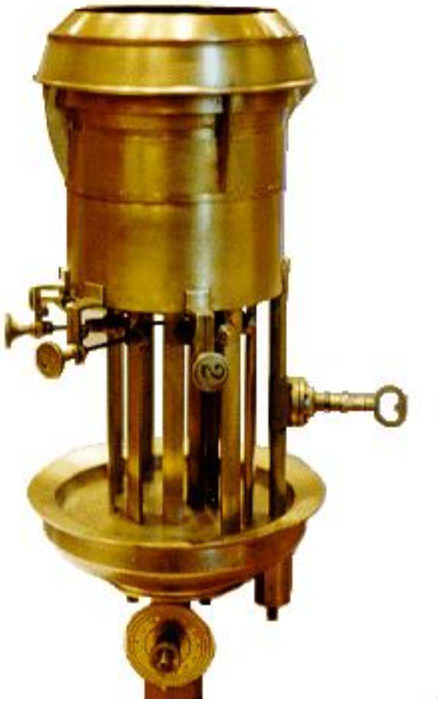
Kerosene Burners

DOTY'S KEROSENE BURNER (1868)

An American ship captain, Henry Harrison Doty, thought he could solve the problems related to the use of kerosene in lighthouse burners. He described his efforts as follows:

"In 1866, the idea occurred to me that if paraffin (Ed: kerosene) as now manufactured, with a large specific gravity and safety standard, could be employed in Lighthouse Illumination, a great reform in the economy and intensity of coast lights would be attained. I accordingly set myself resolutely to the solution of the problem, how this could be affected not only for the one wick burner, but for lamps having concentric wicks. After more than two years unremitting study and experiment, I was successful in discovering the means of doing this for all the different orders of burners, and that too, without causing any structural re-arrangement of the apparatus or lamp at present in use."

Doty mentioned the specific gravity of the kerosene because the heavier the kerosene the less volatile it was, and therefore the safer it was to use.

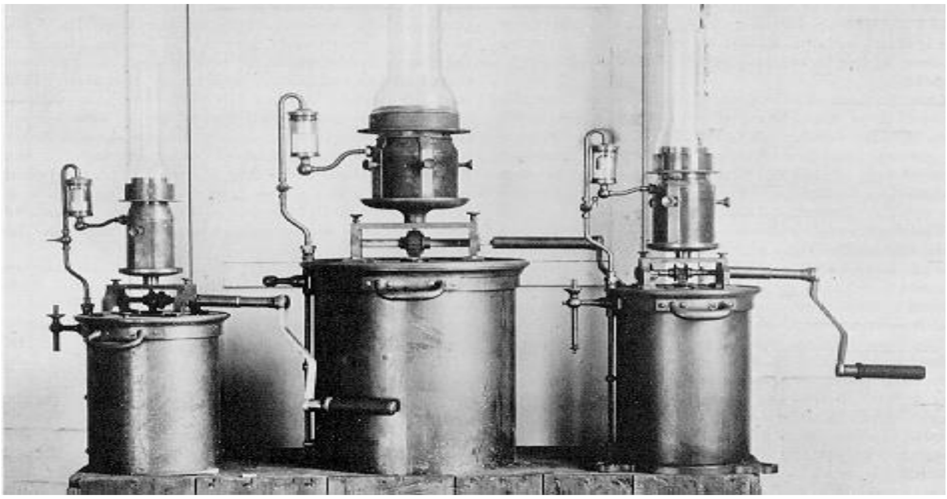


French Five-Wick Lamp based on Doty's patent. (ca. 1873)

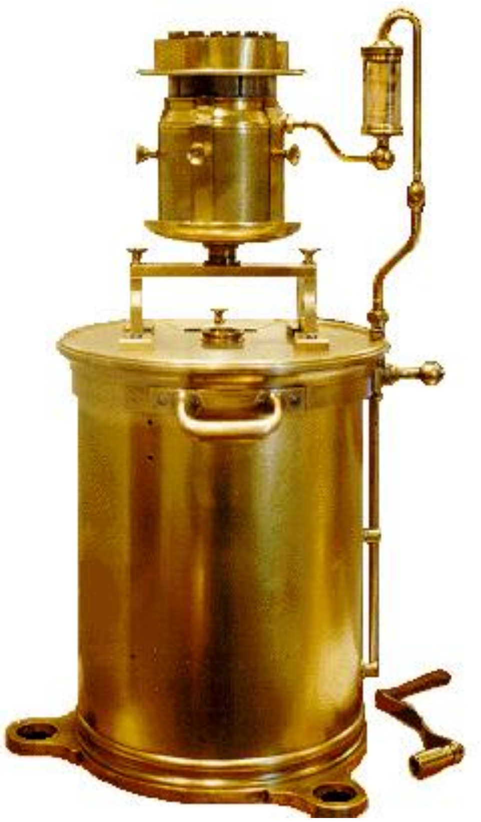
The French Lighthouse Service had long been considered the leader in technical innovation and quality. Captain Doty took samples of his latest burners and went to Emperor Napoleon III in November 1868, convincing him of their advantage and requesting that France put them on trial. Doty's request was granted and a trial within the French Lighthouse Service was begun in December 1868 and completed successfully in January 1869. A number of French lighthouses were then converted to kerosene as a fuel, with the Doty burner modifications. The French did not use the Doty burner directly. Instead, they bought the rights to use Doty's design principals in their own burner designs.

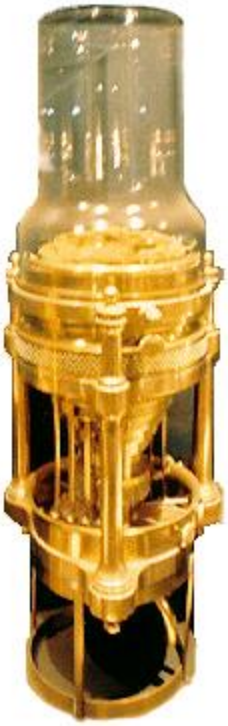
FUNCK'S KEROSENE LAMPS (1876)

Early in 1874, Joseph Funck, the foreman of the Lamp Shop at the Tompkinsville New York Depot, was assigned to begin analyzing any changes necessary in the design of burners for the use of kerosene. Joseph Funck was given a patent for his version of the kerosene burner for lighthouses on November 28, 1876. Captain Doty was continuing to further describe his design and on March 28, 1877, he asked for a second reissue of his patent to describe some additional features of his original design that he felt Funck was infringing upon, and began a lawsuit against the Lighthouse Board and Funck. On December 5, 1878 there was a final decision of the Supreme Court of the District of Columbia. In this decision Funck and the Government won every point and Funck's multi-wick design was declared to be free of any patent infringement related to H. H. Doty or anyone else. The Lighthouse Board now had the right to deploy Funck's multi-wick kerosene burners throughout the system.



(Photo from National Archives 26-LG-16-38) **American Two, Five, and Three-Wick Kerosene Lamps. These lamps are all of the moderator type.**





Joseph Funck's Four-Wick Lamp. (1883) This lamp is of the moderator type.The French 10-Wick Kerosene Burner.

Acetylene

The Acetylene process was invented by a Canadian, Thomas Leopold Willson in 1892. Willson also invented the idea of generating Acetylene inside a buoy in 1904. Acetylene is also sometimes called Dalen gas. When Acetylene is employed in lighthouse work, the gas is either supplied in cylinders, or is generated on the spot.

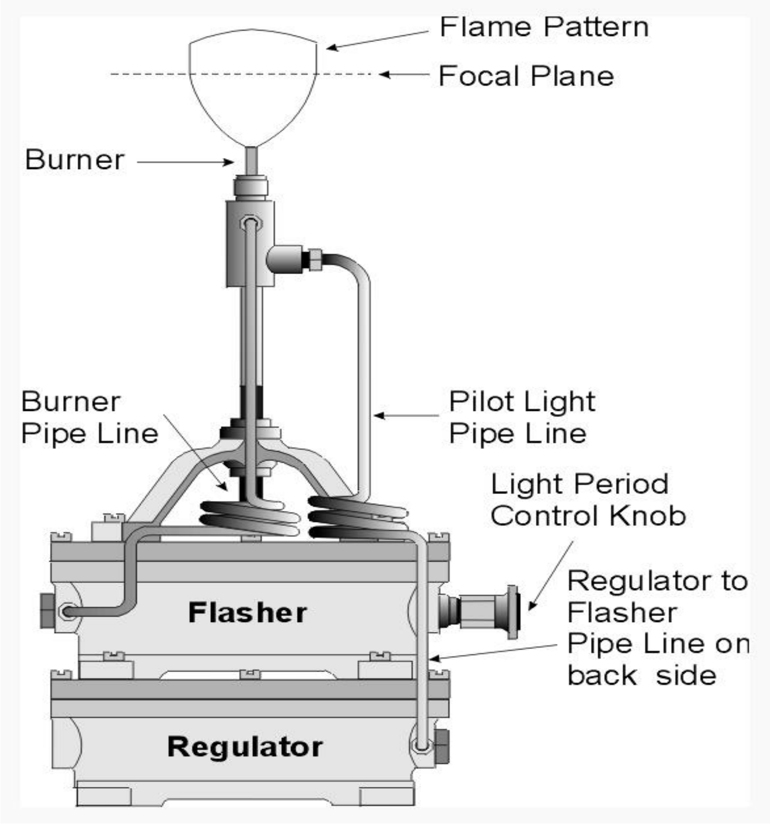
In 1896, two Frenchmen, George Claude and Albert Hess developed a method to store compressed Acetylene by dissolving it in Acetone held in steel cylinders. In this system the gas is compressed into cylinders filled with a porous substance, and with acetone, a liquid having the remarkable power of absorbing at atmospheric pressure twenty-four times its own volume of acetylene gas. Its power to absorb the gas increases in proportion to the pressure, so that at a pressure of ten atmospheres it will dissolve two hundred and forty times its own volume of acetylene gas.

One of the first acetylene gas buoys in the world was designed by David P. Heap, engineer of the Third District depot, in 1897. Heap's buoy used three tanks of compressed acetylene gas to supply a lens lantern, and was used in an experiment conducted in New York harbor.

An acetylene gas lamp was installed at the Cloch lighthouse, in Scotland around 1900, and the acetylene was used to operate everything from the domestic lighting, fog signals and the engine house to the lighthouse lamp itself. In America, a beacon equipped with a generator for producing acetylene gas from calcium carbide was placed in the Mobile Channel in 1902, and this was the first official use of acetylene gas by the American Lighthouse Service. Compressed acetylene was first officially used at Jones Rocks Beacon, Connecticut, and South Hook Beacon, Sandy Hook, New Jersey, in 1903.

In 1904, the development of dissolved acetylene was improved when John Höjer approached the Gasaccumulator Company (later known as the AGA Company), requesting them to redesign the current apparatus. Mr. Gustaf Dalen of Stockholm, Sweden solved the problem with his development of the AGA compound for storing the gas in cylinders. He also invented the acetylene flasher in 1905, which drastically reduced the amount of gas used. An experimental buoy of the Swedish Pilotage Board was installed at Kalmarsund, showing a fixed acetylene light in 1905. In the following year the buoy was first fitted with the Dalen flasher. The Dalen flasher reduced the amount of gas consumed and was proven to need little maintenance.

The American Lighthouse Service chose the Willson carbide-water buoy design rather than the pressurized acetone cylinder type. In the Willson buoy the gas was made on the spot by sliding solid calcium carbide through a canvas chute into a fuel chamber in what was known as the 'charging process'. This process was very dangerous and in 1913 an explosion occurred when refilling such an acetylene chamber in a buoy on the tender Hibiscus. Later, America abandoned the Willson design and began using pressurized cylinders throughout the American Lighthouse Service.

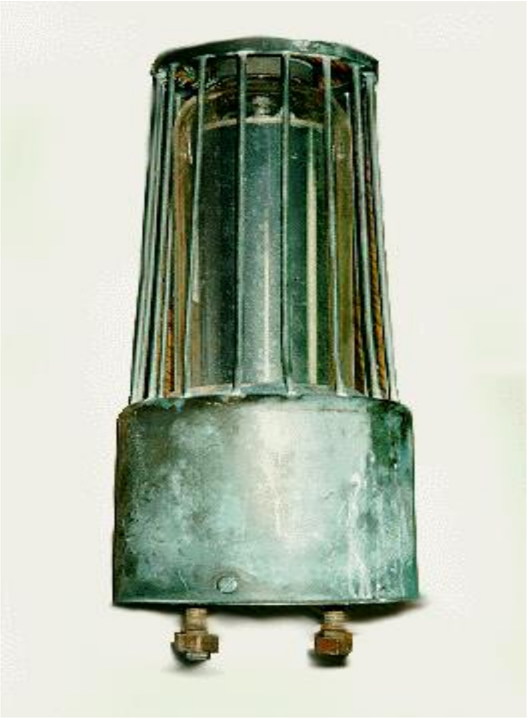


(Drawing by Author) **Acetylene Regulator Flasher Lamp.**

SUN VALVE

The invention of the sun valve became critical to the expanded use of acetylene in lighthouses. Dalen invented the Sun-Valve in 1907 to still further increase the time between gas cylinder replacements. The Sun-Valve consisted of an arrangement of reflective gold-plated copper bars supporting a suspended absorbent black rod. The central black rod absorbs heat from the sunlight and expands closing a small valve at its base and shutting off the supply of gas to the burner (a pilot light is always maintained). When darkness approaches the heat is reduced and the black rod contracts opening the valve and allowing full flow of gas to the burner. The central black rod can be adjusted, by means of a screw, and the entire sun-valve is enclosed in a heavy glass cylinder. The first sun-valve was put into operation in the little Furuholmen lighthouse near

Stockholm in 1907. Later sun-valve designs eliminated the reflective gold-plated bars to reduce the cost of the sun-valve assembly.



An American Sun Valve in its Protective Cage.

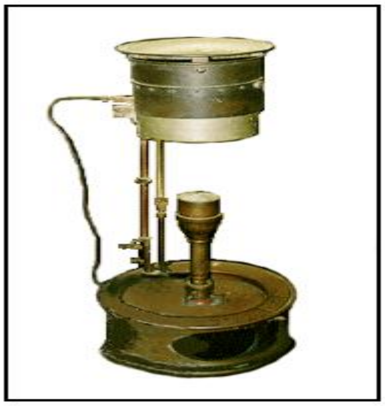
In England, Sir Thomas Matthews created a special clockwork mechanism that was able to time the flash cycles and the turn-on and turn-off times of unattended lights using acetylene fuel. The clockwork was wound automatically by the same mechanism that powered the lens rotation. While its intention was to function similarly to the sun valve, it could not react to storms as the sun valve could, nor was it able to be placed in the open or on buoys.

Matthews' Acetylene Control Clock. The acetylene control valve is at the left center.

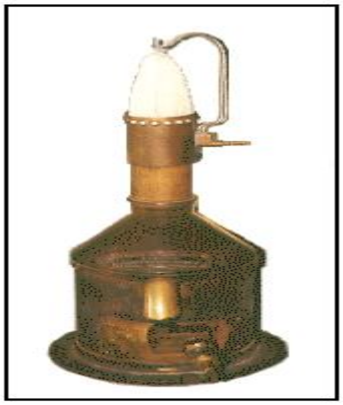
Incandescent Oil Vapor Lamps

One of the first lamps burning gasified oil was developed by Nyberg and Lyth in Sweden in 1881. It worked by vaporizing colza oil and burning it without a mantle as a Bunsen burner does. However, this type of lamp was not efficient at producing additional light output. The next step was the addition of the incandescent gas mantle invented by Carl Auer von Welsbach, in Vienna, in 1885. This led to the first crude kerosene Incandescent Oil Vapor (I.O.V.) lamp, which was installed at the L'lle Penfret lighthouse, by the French, in 1898. It used air pressure and a fuel vaporizer tube where the kerosene was preheated into a fine vapor before it was ignited as a flame. This dramatically increased the oxygen at the flame and provided a brighter flame using less fuel.

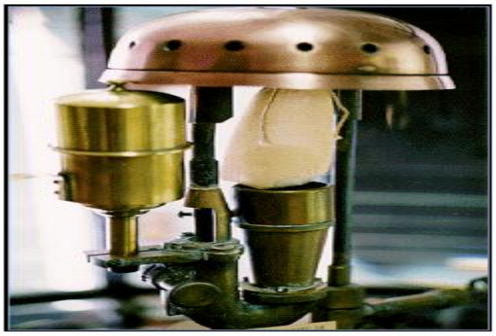
In 1901, Arthur Kitson, an American, invented an improved burner in which the oil was converted into vapor under pressure in a retort and then mixed with air in a mixing chamber to form a gas for heating a mantle made of platinum gauze. The platinum gauze quickly carbonized and within a short time Kitson abandoned it in favor of a Welsbach style incandescent mantle made of silk impregnated with zirconia. This lamp produced at least three times the light output of the Argand style lamps previously used. Another similar incandescent burner was developed by C. W. Scott, the engineer to the Commissioners of Irish Lights in 1902, and still other versions were developed by Sir Thomas Matthews, engineer to the Trinity House in England, Pintsch in Germany and by Luchaire in France and Diamond in Canada. The I.O.V. lamp was first used in America at the Sandy Hook lighthouse in 1904. Matthews, in England, invented the triple mantle I.O.V. lamp around 1904 and the American Lighthouse Service began testing this lamp in 1913. One of these lamps was first used in America in 1916 at the Cape Lookout lighthouse. Finally in 1921, David Hood further improved and simplified the Kitson burner.



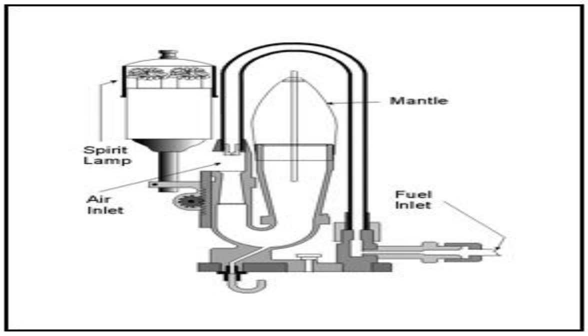
(Photo from Author's collection)
The original Kitson I.O.V. Lamp. (1901) as modified by Matthews



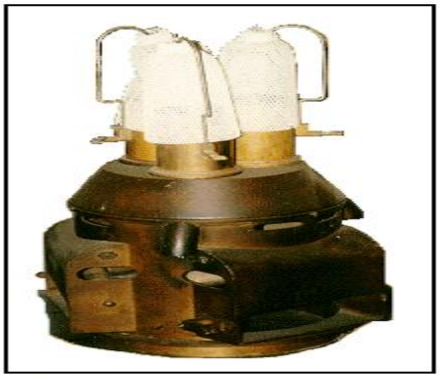
(Photo from Author's collection)
An early Chance Brothers' I.O.V. Lamp. (ca. 1904)



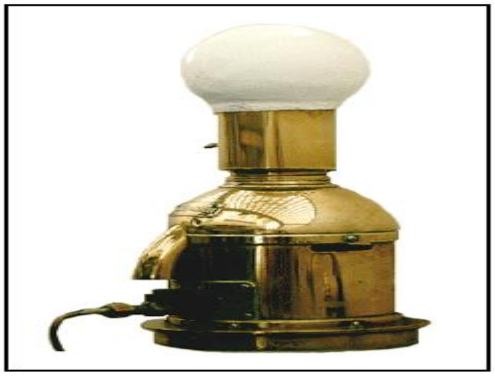
(Photo from Author's collection)
French Luchaire I.O.V. Lamp. (ca. 1904)



(Drawing by Author from official drawing)
French Luchaire I.O.V. Lamp Burner cutaway view.



(Photo from Author's collection)
Chance Brothers' version of a triple mantle I.O.V. Lamp. (ca. 1911)



(Photo from Author's collection)
D. W. Hood I.O.V. Lamp with autoform mantle. (1921)

Electricity

Electricity was not available in lighthouses before 1857. The electric arc had been demonstrated by Sir Humphry Davy in 1808-9. François Arago, who worked with Augustin Fresnel to develop the multiple-concentric-wick-oil lamp, also worked on the arc lamp during 1820. In 1836, Michael Faraday suggested that trials be made using arc lamps in lighthouses in England; however, it was not until 1853, when Professor Holmes made the first crude magneto-electric generator to power an arc lamp for use in a lighthouse. The first trial of this machine was made by the Trinity House, in England, in 1857. Also in 1857, Monsieur V. L. M. Serrin, in France, invented an arc lamp with automatic adjustment of the carbon rods through the use of a clockwork mechanism and electrical solenoids. Serrin's lamp was further improved by Monsieur Lontin.

In 1858, at the request of Professor Faraday, an Alliance magneto-electric generator, modified by Professor Holmes, was tested at South Foreland lighthouse, in England, and the electric arc light was first shown to the mariner. Holmes' machine was able to generate electricity, which was applied to two tiny 6 ¼ mm.-square-carbon rods between which a spark, or arc, was drawn by means of the electric current. The intense heat generated by the electric current liquefied a portion of the carbon rods as the current passed from one carbon point to the other. The carbon points had to remain the same distance from each other in order for the lamp to properly function. Serrin's clockwork mechanism was designed to move the carbon rods and maintain the distance for the electric arc.

The electric-arc lamp was officially installed at Dungeness, England (old tower) in 1862, a Serrin lamp was first used in France at the Cape La Heve lighthouse in 1863, and other installations soon followed. In America, experiments with the Electric light in 1868 included the use of a magneto machine made by Mr. Wilde of Liverpool. Progress was also being made in other countries. In Germany, Werner Siemens invented the dynamo generator in 1866, which proved far more reliable than the generators previously used.

In 1869, Professor Holmes constructed a new dynamo-electric generator for Trinity House. The invention of the dynamo brought the first break-through in electric lighting by supplying a constant and reliable current to feed the lamp. The second breakthrough was the development of carbon rods with softer cores in 1877. These new style carbon rods had the ability to more easily maintain the arc in the center of the rod, giving a brighter and steadier light.

Various experiments were carried out in 1876-77 and again in 1883-84 at South Foreland to determine the best machine for generating electricity and to compare electric lights with oil and gaslights. Later, in 1885, three De Meritens alternating-current magneto generators along with three arc lamps of the Duboscq-Gaiffe model were put on trial.

The carbon rods first used were the De Meritens pattern, square in section and made up of smaller carbons. These carbons were found ineffective, because the interior of the upper carbon had a tendency to fall out as the bands binding it together burned up during the consumption of the carbon. Later, cylindrical carbons up to 40 millimeters in diameter were used, the most effective being the 30-millimeter Berlin core carbon, which had a core of graphite 3 millimeters in diameter. Sir James Douglass invented a rod with fluted sides that provided additional steadiness to the arc, and soon larger carbons up to 50 millimeters diameter were tried.

The brilliance of the arc lights far exceeded any earlier oil lamp, but there were differing views about their penetration ability during fog. It was first thought that light produced from electricity would not penetrate fog to anywhere near the extent that the light from an oil lamp could, because the oil lamp produced a light that was strong in the yellow-orange-red part of the spectrum and the light from the electric arc was in the blue portion of the spectrum. Later, this was found to be false through the trials held at the South Foreland Lighthouse in 1884.

In America, experiments were also conducted on electricity and arc lamps during 1885 and the Lighthouse Board reported on the experiments as follows:

“It will be necessary to state first the reasons, which appear to have prevented the adoption in our service of electric lighting apparatus of the pattern now being introduced to a considerable extent in the lighthouses of foreign countries. The principal objections to the adoption of the new light, in its present form, are the expense of installation and the increased cost of maintenance.

For the present at least, and until the complete reliability of the new light under the keepers' management shall be established, the advantage offered by an electric light, while being greatly superior in intensity to the oil lamp, would require alteration of the lantern or lens. The construction of an incandescent electric lamp adapted for this purpose, and designed so as to give the maximum amount of illumination in the most efficient direction, would best meet our needs. In the progress of this work many serious difficulties were encountered, but a practicable lamp much superior in luminous intensity and compactness to the first-order flame was produced. But, a lamp with satisfactory luminous intensity, justifying the establishment of a steam-plant to produce it, has not yet been attained, although there has been continued progress in this respect.

Regarding the superiority of the arc-electric light over all other modes of illumination yet developed for primary seacoast lights there can no longer be any question. This fact was definitely established by the very exhaustive experiments made at South Foreland, England, by a committee of the Trinity House, as stated in their report of August 1885. It is further sustained by the increasing number of electric lighthouses in actual operation and the favor with which they are received by mariners.

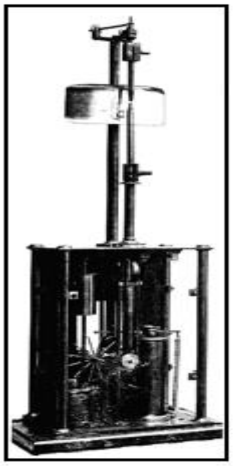
The first electrically lit light in America was the Statue of Liberty in 1886. The statue served as a lighthouse beacon for seventeen years.

The first American buoy lit with electricity was a series of spar buoys in Gedney's Channel in New York harbor in 1888. Unfortunately the underwater power cables kept breaking and the project was finally abandoned in 1903. The electric light was first installed in an American lighthouse at Navesink in 1898.

America's first lightship using electric illumination was the Cornfield Point light-ship, No. 51, delivered to the Staten Island Depot in July 1892. The Lighthouse Board reported that the lightship operated in a highly satisfactory manner when deployed. Tests were also run on the electric light at Hallet's Point NY, known as the Hell Gate electric light.

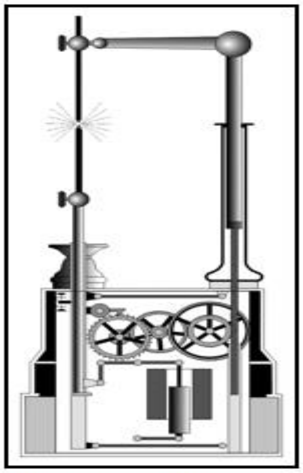
In 1905, the Germans (Prussians) invented the 'Differential Arc Lamp,' where the positive carbon rod is held horizontally and the negative carbon rod is placed at a seventy-seven-degree angle to the positive rod. The German engineers felt that the Differential Arc Lamp allowed better control of the arc within the focus of a reflector or lens.

Arc Lamps



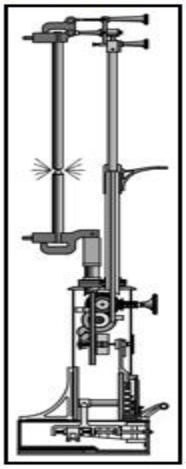
(Photo from Author's collection)

Holmes' Arc Lamp with regulator. (1857)



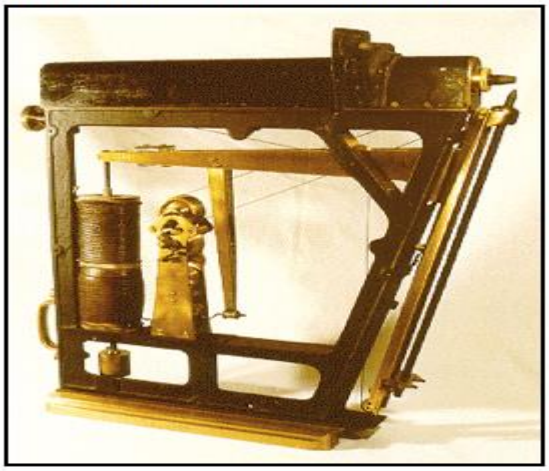
(Drawing by Author)

Serrin's Arc Lamp with regulator. (1857)



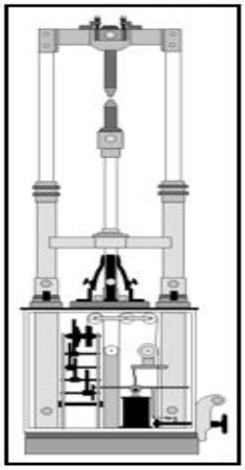
(Drawing by Author)

Siemens' Arc Lamp. (1878)



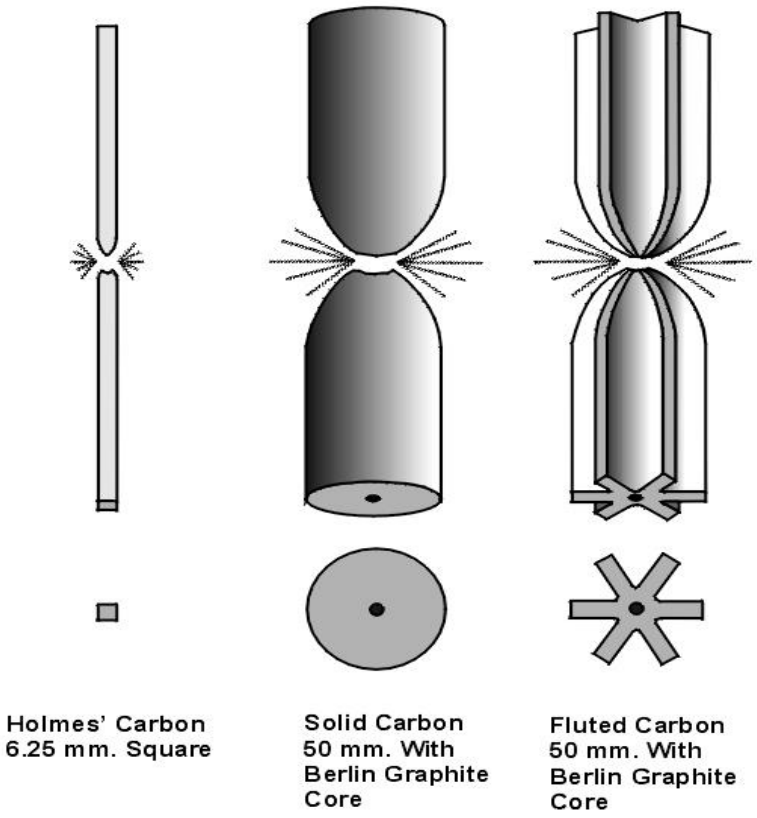
(Photo from Egbert Koch collection)

Prussian Differential Arc Lamp with the carbon points set at a 77 degree angle. (1905)



(Drawing by Author)

French Arc Lamp. (ca. 1900) Both upper and lower carbons movable by action of the regulator.



Some of the Types of Carbon Rods used in Arc Lamps.

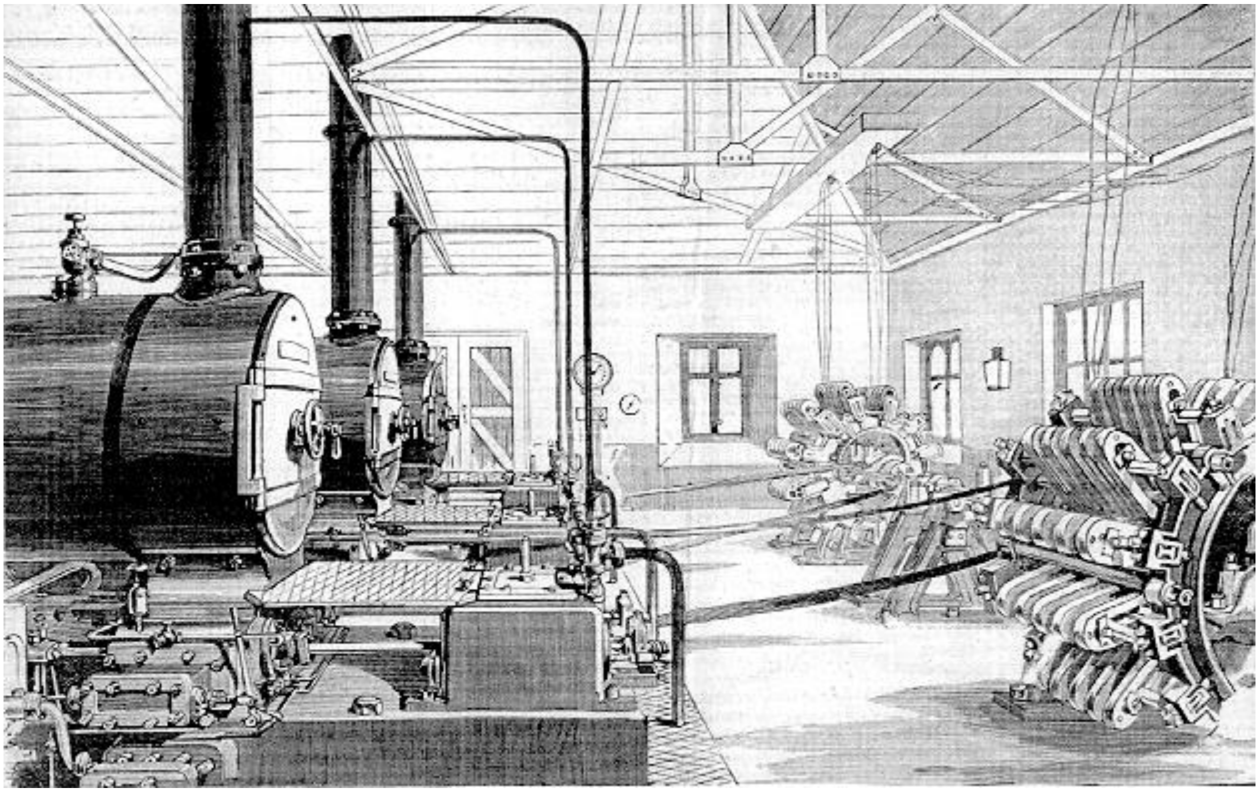
The carbon rods used in Arc lamps varied in size based on the amount of electrical current applied.

CURRENT APPLIED	DIAMETER of ROD
25 Amps	10 mm.
50 Amps	16 mm.
100 Amps	23 mm.

- Larger carbon rods of 50 mm. and more in size were also produced.

DE MERITENS MAGNETO GENERATOR

The French De Meritens magneto generators were found to work with great steadiness and with good efficiency, revolving at 600 rpm. A De Meritens magneto was installed at the Lizard lighthouse, in England, and was used from 1881 until May 1950. It produced 32v at 120 cycles, giving an AC output of 3.5kw, and ran the arc lights at the station until 1926. The arc lights were then replaced with filament bulbs of 3kw, and the voltage from the De Meritens generator was transformed up to 80v.



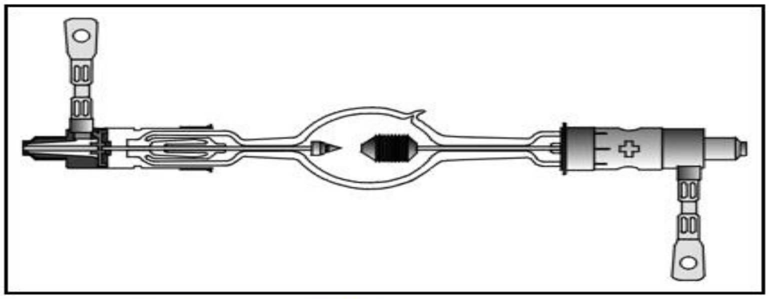
(Drawing from old newspaper) **Steam Engines and De Meritens Generators in the Generator Room at the Lizard Lighthouse, England. (1881)**

Modern Electric Lamps

The early incandescent light bulbs were very unreliable and while they were experimented with at many locations they were not put into use. It was after Thomas Edison invented the tungsten filament light bulb that similar (but much larger) bulbs were used in lighthouses. Bulbs of 1000-3000 watts replaced arc lights in many lighthouses in the early 1900s.

When commercial power became available the first station to be connected in England was South Foreland, and in 1922 it became the first British lighthouse to be lit by an incandescent lamp. These early lamps had very large globes and optical difficulties were encountered as the filaments presented a complex patterned light source, later bulbs became smaller and the filaments were made smaller as well. The Xenon discharge lamp, first introduced in 1947, gave a highly concentrated light source. It has one drawback in that its beam is very vertically narrow and the beam provides little, if any, of the ‘loom’ in the sky that mariners prefer to see. Later, in the Terschelling, Brandaris and other Dutch lighthouses, old incandescent bulbs were replaced by a super-high pressure mercury-iodine lamp, and in the United States, and elsewhere, various forms of Halogen lamp bulbs are now the norm.

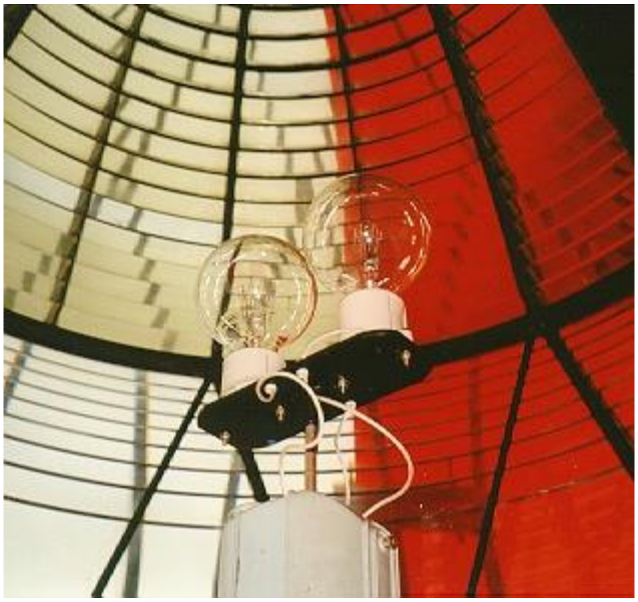
BULBS



(Drawing by Author from OSRAM drawing)
Drawing of a 2000-Watt Xenon Lamp. (1947)

(Photo from the Egbert Koch collection)
English 1000-Watt, Metal-Halide Lamp.

(Photo from Author’s collection)
American 1000-Watt Halogen Lamp.



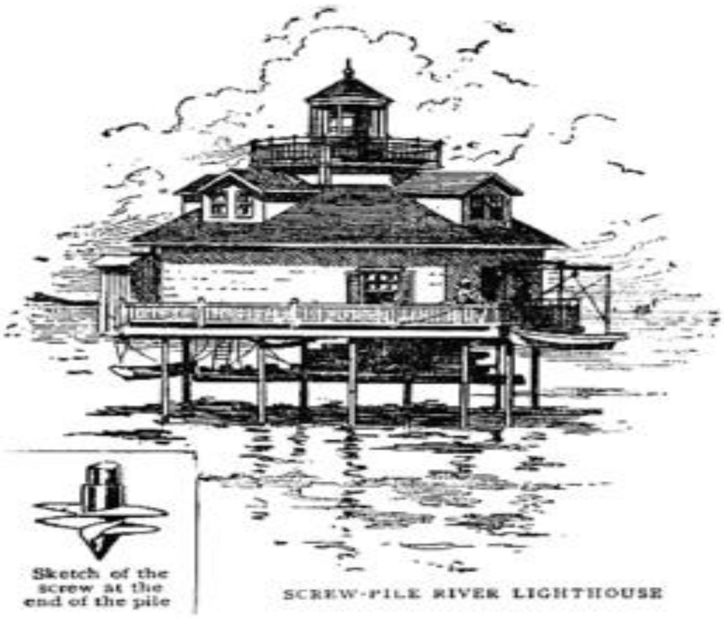
(Photo from the Egbert Koch collection) **Modern Lamp Bulbs in a Dual Changer.**

The light sources used in lighthouses changed significantly over the years. Many styles of light sources were tried, some were a great success and some proved of little value. Yet all forms, ‘From Braziers and Bougies to Xenon,’ helped to make the lives of the mariners safer.

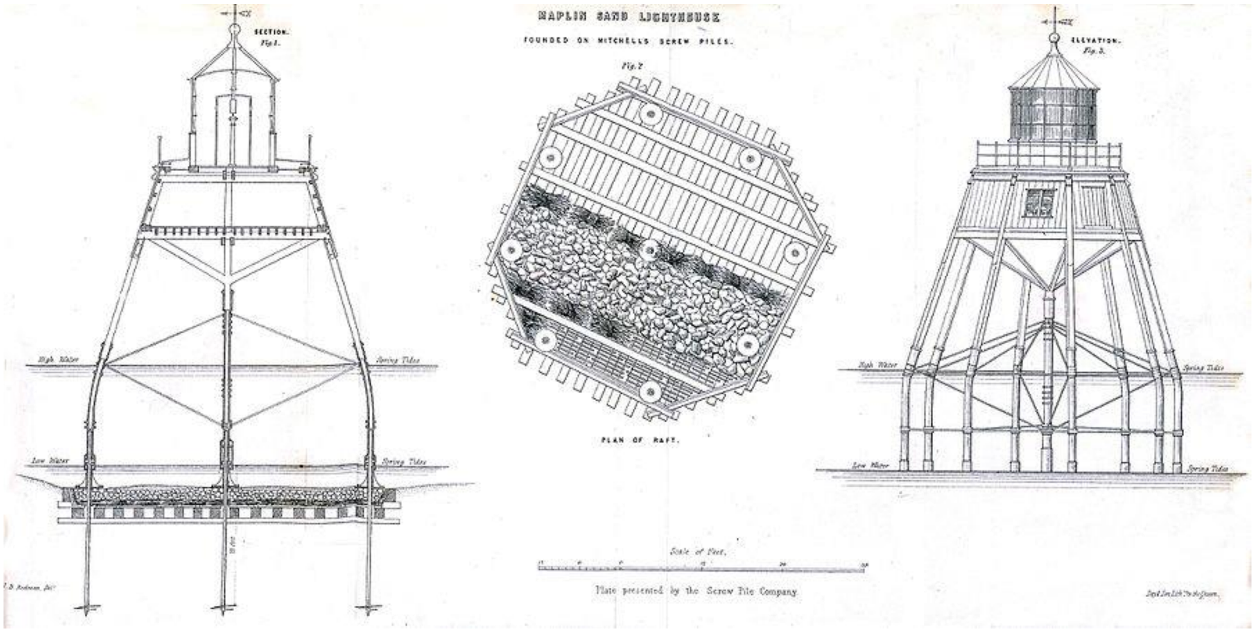
A Note About Candlepower

The determination of the light output of lamps is usually measured in candlepower. In the early years of lamp development there were no accurate methods of measuring candlepower and later, in the early 1800s the methods used were very subjective and unscientific by our current standards. The candlepower is also dramatically affected by the size of the flame, the type of oil used as a fuel, the maintenance of the lamp and polish of the reflector and by other factors such as the clarity of the air and alignment of the reflector with the horizon. In describing the various apparatus in this story I have used the candlepower ratings developed or estimated by the various inventors. However, the candlepower ratings should only be used as a very rough estimate of the relative power of each instrument as compared to the others and not as a true rating of its actual light output.

Screw-pile lighthouse


Sketch of the screw at the end of the pile
SCREW-PILE RIVER LIGHTHOUSE

Screw-pile lighthouse from *Sea Stories*, publ. 1910 by Century Co. N.Y.



Maplin Sands screw-pile lighthouse (drawing published by Alexander Mitchell & Son in 1848)

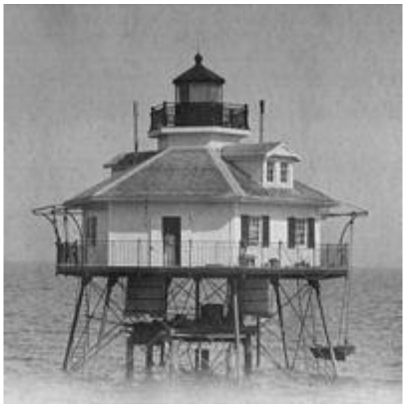
A **screw-pile lighthouse** is a lighthouse which stands on piles that are screwed into sandy or muddy sea or river bottoms. The first screw-pile lighthouse to begin construction was built by the blind Irish engineer Alexander Mitchell. Construction began in 1838 at the mouth of the Thames and was known as the Maplin Sands lighthouse, and first lit in 1841.[1] However, though its construction began later, the Wyre Light in Fleetwood, Lancashire, was the first to be lit (in 1840).

In the United States, several screw-pile lighthouses were constructed in the Chesapeake Bay due to its estuarial soft bottom. North Carolina's sounds and river entrances also once had many screw-pile lights. The characteristic design is a 1 ½-storey hexagonal wooden building with dormers and a cupola light room.

History; Non-screwpile (straightpile) tubular skeletal tower lighthouses were built, usually of cast-iron but also of wrought-iron piles, both onshore and offshore, typically on soft bottoms such as mud, sand, and swamp. Alexander Mitchell invented the screwpile, a major improvement over the standard straightpile construction type. With his son, he patented his wrought-iron screwpile design in England in 1833. The Walde Lighthouse in northern France (Pas-de-Calais), established in 1859, was based on Mitchell's design. Although discontinued in 1998 and shorn of its lantern, it is the only remaining screwpile lighthouse in France.

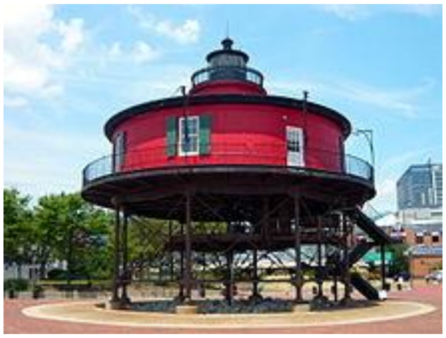
Screw-pile lighthouses in the United States

The first screwpile lighthouse type built in the United States was at Brandywine Shoal, Delaware Bay, an area served by a lightship since 1823 and an ordinary straightpile lighthouse which stood briefly there in 1828 but was destroyed by ice. Major Hartman Bache, a distinguished engineer of the Army Corps of Topographical Engineers, began work in 1848 and completed the task in 1850, at a construction cost of $53,317. Alexander Mitchell served as consultant. The screwpiles were turned by a 4-foot capstan worked by 30 men. To protect the structure from ice floes an ice-breaker consisting of a pier of 30 iron screwpiles 23 feet long and five inches in diameter was screwed down into the bottom and interconnected at their heads above the water reinforcing them together. Subsequently, though, the use of caisson lighthouses proved more durable in locations subject to ice.



Middle Bay Lighthouse in Mobile Bay

Screwpile lighthouses were relatively inexpensive, easy to construct, and comparatively quick to build. They became especially popular after the Civil War when the Lighthouse Board adopted a policy to replace inside (bays, sounds, and rivers) light vessels with screwpile lighthouses. Most screwpile lighthouses were made with iron piles, though a few were made with wooden piles covered with metal screw sleeves (these sleeves were probably adopted because they were less expensive and easier to insert into the bottom, plus the sleeve protected the wood from marine-boring invertebrates). The typical screwpile lighthouse was hexagonal or octagonal in plan consisting of a central pile which was set first and then the six or eight perimeter piles were screwed in place around it.

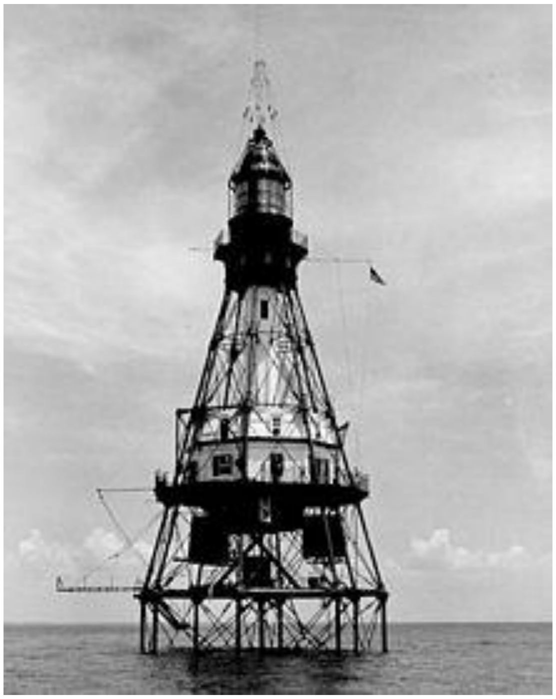


Seven Foot Knoll Lighthouse, Inner Harbor, Baltimore, Maryland

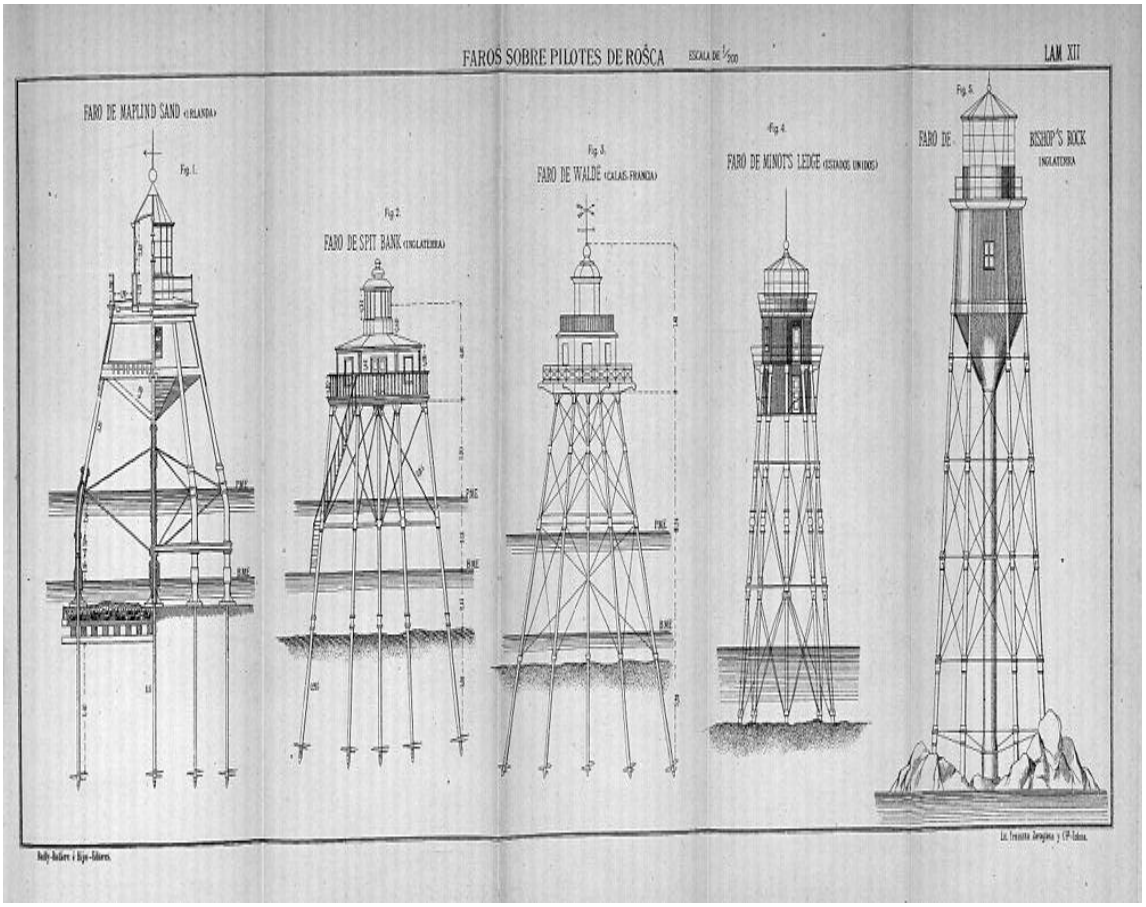
Metal screwpiles were used to form the foundation of many lighthouses built on sandy or muddy bottoms. The helicoidal or screw-like cast-iron flange at the end of the metal pile was augured into the bottom increasing the bearing capacity of the pile as well as its anchoring properties. Yet lighthouses built with these foundations were found to be vulnerable to ice floes. In areas such as the Florida Keys, where the bottom is soft coral rock, diskpile foundation lighthouses were built.

Wrought iron piles were driven through a cast-iron or semi-steel disk which rested on the sea floor until a shoulder on the pile prevented further penetration. The disk distributes the weight of the tower more evenly over the bottom. In coral reef areas where sand is also prevalent, a cast-steel screw was fitted to the end of the pile to give it more anchoring ability. Cofferdams were used generally in shallow waters where it was not necessary to deeply penetrate the natural bottom. The cofferdam enabled the water inside the dam to be pumped out and the foundation built "in the dry".

Perhaps as many as 100 spider-like, cottage-type (1½-storey wooden dwelling) screwpile lighthouses were built throughout the Carolina sounds, Chesapeake Bay, Delaware Bay, along the Gulf of Mexico, at least two in Long Island Sound and one even at Maumee Bay (1855), Lake Erie, Ohio. Few survive to this day; many were replaced with caisson-type lighthouses. The tall offshore skeletal tower type was built in exposed open water at major coastal sites where visibility over ten miles was required. Six offshore skeletal towers were built in Florida; three before and three after the American Civil War, as well as one in the Gulf of Mexico off Louisiana prior to the Civil War.



Fowey Rocks Light, near Key Biscayne, Florida


FAROS SOBRE PILOTES DE ROSCA
ESCALA DE 1/200
LAM XII
FARO DE MAPLIND SAND (IRLANDA)
Fig. 1.
Fig. 2.
FARO DE SPIT BANK (INGLATERRA)
Fig. 3.
FARO DE WALDE (CALAIS FRANCIA)
Fig. 4.
FARO DE MINOT'S LEDGE (ESTADOS UNIDOS)
Fig. 5.
FARO DE BISHOP'S ROCK
INGLATERRA

Examples of rock screw-pile lighthouses from a drawing by José Eugenio Ribera.[4]
Lighthouse,Ian C. Clingan

Lighthouse, structure, usually with a tower, built onshore or on the seabed to serve as an aid to maritime coastal navigation, warning mariners of hazards, establishing their position, and guiding them to their destinations. From the sea a lighthouse may be identified by the distinctive shape or colour of its structure, by the colour or flash pattern of its light, or by the coded pattern of its radio signal. The development of electronic navigation systems has had a great effect on the role of lighthouses. Powerful lights are becoming superfluous, especially for landfall, but there has been a significant increase in minor lights and lighted buoys, which are still necessary to guide the navigator through busy and often tortuous coastal waters and harbour approaches. Among mariners there is still a natural preference for the reassurance of visual navigation, and lighted marks also have the advantages of simplicity, reliability, and low cost. In addition, they can be used by vessels with no special equipment on board, providing the ultimate backup against the failure of more sophisticated systems.

Lighthouse at Portsmouth, N.H.*Dave Shafer/© New Hampshire Division of Travel and Tourism Development*

Lighthouses of antiquity

The forerunners of lighthouses proper were beacon fires kindled on hilltops, the earliest references to which are contained in the *Iliad* and the *Odyssey* (*c.* 8th century BCE). The first authenticated lighthouse was the renowned Pharos of Alexandria, which stood some 350 feet (about 110 metres) high. The Romans erected many lighthouse towers in the course of expanding their empire, and by 400 CE there were some 30 in service from the Black Sea to the Atlantic. These included a famous lighthouse at Ostia, the port of Rome, completed in 50 CE, and lighthouses at Boulogne, France, and Dover, England. A fragment of the original Roman lighthouse at Dover still survives.

The Phoenicians, trading from the Mediterranean to Great Britain, marked their route with lighthouses. These early lighthouses had wood fires or torches burning in the open, sometimes protected by a roof. After the 1st century CE, candles or oil lamps were used in lanterns with panes of glass or horn.

Medieval lighthouses

The decline of commerce in the Dark Ages halted lighthouse construction until the revival of trade in Europe about 1100 CE. The lead in establishing new lighthouses was taken by Italy and France. By 1500, references to lighthouses became a regular feature of books of travel and charts. By 1600, at least 30 major beacons existed.

These early lights were similar to those of antiquity, burning mainly wood, coal, or torches in the open, although oil lamps and candles were also used. A famous lighthouse of this period was the Lanterna of Genoa in Italy, probably established about 1139. It was rebuilt completely in 1544 as the impressive tower that remains a conspicuous seamark today. The keeper of the light in 1449 was Antonio Columbo, uncle of the Columbus who crossed the Atlantic. Another early lighthouse was built at Meloria, Italy, in 1157, which was replaced in 1304 by a lighthouse on an isolated rock at Livorno. In France the Roman tower at Boulogne was repaired by the emperor Charlemagne in 800. It lasted until 1644, when it collapsed owing to undermining of the cliff. The most famous French lighthouse of this period was one on the small island of Cordouan in the estuary of the Gironde River near Bordeaux. The original was built by Edward the Black Prince in the 14th century. In 1584 Louis de Foix, an engineer and architect, undertook the construction of a new light, which was one of the most ambitious and magnificent achievements of its day. It was 135 feet in diameter at the base and 100 feet high, with an elaborate interior of vaulted rooms, richly decorated throughout with a profusion of gilt, carved statuary, and arched doorways. It took 27 years to build, owing to subsidence of the apparently substantial island. By the time the tower was completed in 1611, the island was completely submerged at high water. Cordouan thus became the first lighthouse to be built in the open sea, the true forerunner of such rock structures as the Eddystone Lighthouse.

The influence of the Hanseatic League helped increase the number of lighthouses along the Scandinavian and German coasts. At least 15 lights were established by 1600, making it one of the best-lighted areas of that time.
During this period, lights exhibited from chapels and churches on the coast frequently substituted for lighthouses proper, particularly in Great Britain.

The beginning of the modern era

The development of modern lighthouses can be said to have started about 1700, when improvements in structures and lighting equipment began to appear more rapidly. In particular, that century saw the first construction of towers fully exposed to the open sea. The first of these was Henry Winstanley's 120-foot-high wooden tower on the notorious Eddystone Rocks off Plymouth, England. Although anchored by 12 iron stanchions laboriously grouted into exceptionally hard red rock, it lasted only from 1699 to 1703, when it was swept away without a trace in a storm of exceptional severity; its designer and builder, in the lighthouse at the time, perished with it. It was followed in 1708 by a second wooden tower, constructed by John Rudyerd, which was destroyed by fire in 1755. Rudyerd's lighthouse was followed by John Smeaton's famous masonry tower in 1759. Smeaton, a professional engineer, embodied an important new principle in its construction whereby masonry blocks were dovetailed together in an interlocking pattern. Despite the dovetailing feature, the tower largely relied on its own weight for stability—a principle that required it to be larger at the base and tapered toward the top. Instead of a straight conical taper, though, Smeaton gave the structure a curved profile. Not only was the curve visually attractive, but it also served to dissipate some of the energy of wave impact by directing the waves to sweep up the walls.

Owing to the undermining of the foundation rock, Smeaton's tower had to be replaced in 1882 by the present lighthouse, constructed on an adjacent part of the rocks by Sir James N. Douglass, engineer-in-chief of Trinity House. In order to reduce the tendency of waves to break over the lantern during severe storms (a problem often encountered with Smeaton's tower), Douglass had the new tower built on a massive cylindrical base that absorbed some of the energy of incoming seas. The upper portion of Smeaton's lighthouse was dismantled and rebuilt on Plymouth Hoe, where it still stands as a monument; the lower portion or "stump" can still be seen on the Eddystone Rocks.

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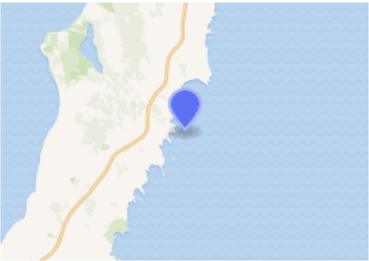
Eddystone Lighthouse: Sir James N. Douglass's version Sir James N. Douglass's Eddystone Lighthouse, Plymouth, England, photochrome print, *c*. 1890–1900.

Following the Eddystone, masonry towers were erected in similar open-sea sites, which include the Smalls, off the Welsh coast; Bell Rock in Scotland; South Rock in Ireland; and Minots Ledge off Boston, Massachusetts, U.S. The first lighthouse of the North American continent, built in 1716, was on the island of Little Brewster, also off Boston. By 1820 there were an estimated 250 major lighthouses in the world.

lighthouseLighthouse at Beachy Head, a chalk headland near Eastbourne, East Sussex, England, on the English Channel coast. It was automated in 1983.© *Alison Platt Kendall*

Högby Lighthouse is a Swedish lightstation. The lighthouse is built of iron and painted white. The design by architect Johan Höjer is unique to Sweden. The tower was exhibited at the Stockholm Exposition in 1897 before being located in Högby on a narrow peninsula. The flame ran on kerosene at first, and was updated with a gas mantle light in 1908. It was electrified in 1945 with a 1000 watt bulb and fully automated in 1967. Today the light runs with a faint 60 watt bulb, and the old rotating Fresnel lens has been replaced. The lighthouse is owned by The Swedish Maritime Administration.

Both the keeper's house and lighthouse is protected as a culturally important building since 1978. Today the keeper's house is a private residence to an artist and contains an art studio and showroom.



BIBLIOGRAPHY

1. **The Ultimate Book of Lighthouses: An Illustrated Companion to the History ...**
   By Michael J. Rhein, Samuel Willard Compton

2. ***Pioneers in the Optical Sciences***
   https://micro.magnet.fsu.edu/optics/timeline/people/index.html
3. **.LIGHTHOUSE EVOLUTION & TYPOLOGY,**. Robert Browning, Historian,
   http://www.seashellshop.com/Lighthouse-Evolution-and-Typology/

4. **LIGHTHOUSE EVOLUTION & TYPOLOGY,**. Robert Browning, Historian,
   http://www.seashellshop.com/Lighthouse-Evolution-and-Typology/

The above two chapters are based on these erudite writers' accounts in the bibliography

CHAPTER XI
Nudes and Light Houses

What spirit is so empty and blind, that it cannot recognize the fact that the foot is more noble than the shoe, and skin more beautiful that the garment with which it is clothed? - MichaelAngelo

Just as there are stories of haunted light houses, many pictures of these towers feature nude female in the foreground or background of light houses. The reason is not difficult to understand –both enhance the beauty of each other. A nude person—particularly in *contrapposto*—exists outside of the context of time, geography, and social class. It is a distilled portrayal and celebration of the human form, which can be understood and appreciated by a broader range of people.

It can simultaneously reference old masters while being sourced from a contemporary subject. The slightest additions and changes can add complex emotions, social commentary, and sensuality or eroticism; for conveying human experience it is one of the most crucial key ingredients to study.

It’s also a key part of art instruction, as a foundation between basic concepts (drawings of cubes, vases, and such) and the more advanced art of creating a setting, draping fabric, and having your subject interact with the environment. For that reason, it can be a useful daily exercise to keep your abilities sharp for more finished pieces.

It’s a central concept in art, much like color palettes and landscapes. It is because of its importance and potential that so many people are drawn to it.
See for instance- https://www.shutterstock.com/search/lighthouse+woman

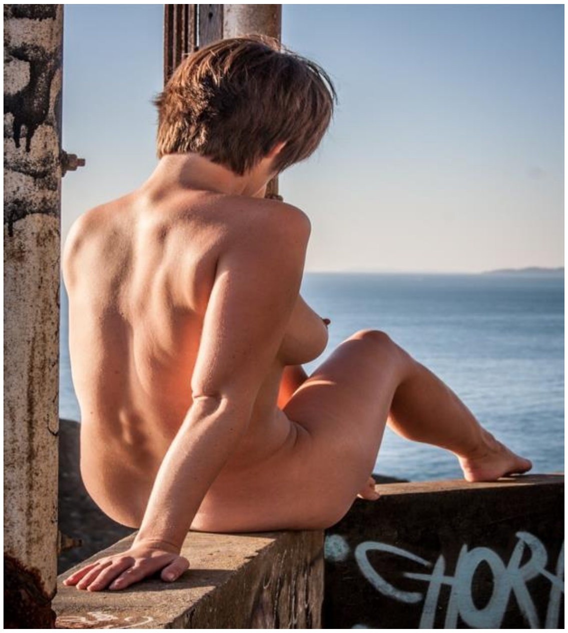
Spencer Tunick Corrals 300 Naked People in Front of Montauk Lighthouse
By Flavorwire Staff.June 25, 2009 https://www.flavorwire.com/26939/exclusive-spencer-tunick-corrals-300-naked-people-in-front-of-montauk-lighthouse

Educational issues aside, nude figures also offer important expressive tools to artists. They can show human beings in ways that are uniquely valuable. For one thing, expressions of nudes are the extreme opposite of expressions of figures wearing trench coats, hats, and dark sunglasses. They also allow the artist to show people outside of a historical context if he wishes to do so. Put any kind of clothing on a person in a painting or a sculpture and you tie them down to a time when that kind of clothing was common or popular and apart from times when it wasn't.

That said, at times the figures need to wear clothing due to the nature of what is being portrayed, yet the artist may still wish the message to be universal to all men of all times. One way of doing this has been to dress the figures in a sheet or simple cloth which is often called classical garb which drapes the figures and feels like it could be taking place in the past present or future. I like to call this placing the figures in the "ancient distant future".

Using nudity and the light house the artist can show two eternal symbols of salvation -human beings in a way that focuses the attention on the figure and not irrelevant matters like how their shirts are buttoned, how their skirts are being draped, and whether they are wearing the most stylish kind of hat. The ability of the artist to focus attention on the important aspects of what is going on and to remove distractions from this subject of focus is a common reason for the choice of nude figures as well.

Lastly, the human body can be a beautiful thing to contemplate and this can be a useful artistic tool in and of itself, just as flowers, sunsets, and mountains are similarly useful tools in the artist's toolkit. And if the point of art is primarily to express ideas about the nature of humanity, man's role in the world then it would be natural to expect that the unadorned human form would be among the most powerful of those expressive tools and indeed it is. Some non –nude women in associated with light houses are also pleasing to the eye. Georges Seurat: The Drawings has done numerous nudes in the light house context.(See George Seurat By Georges Seurat, Jodi Hauptman, Karl D. Buchberg, Hubert Damisch, Bridget Riley, Richard Thomson, Richard Shiff, Infibeam books.



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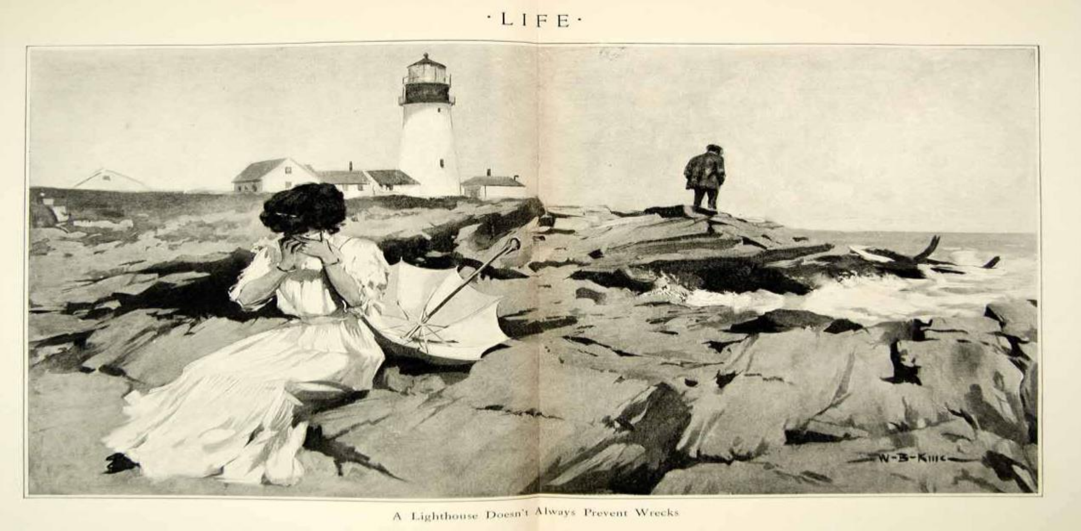
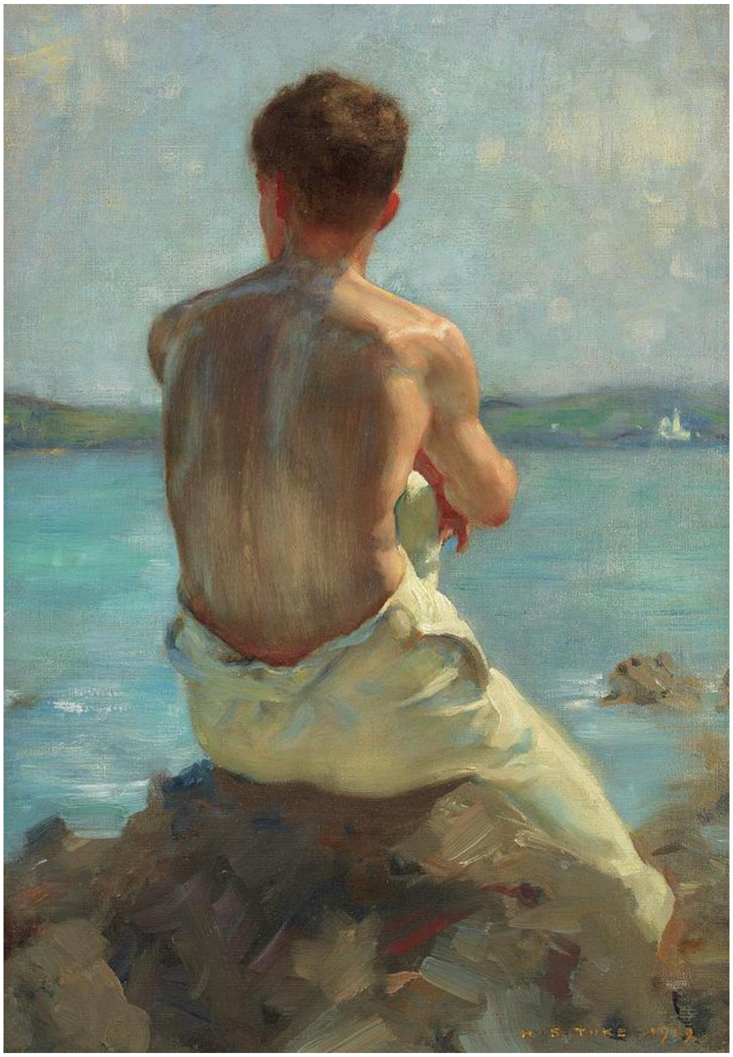
1910 Print William Balfour Ker Art Lighthouse Edwardian Lovers Romance Sea YLF5



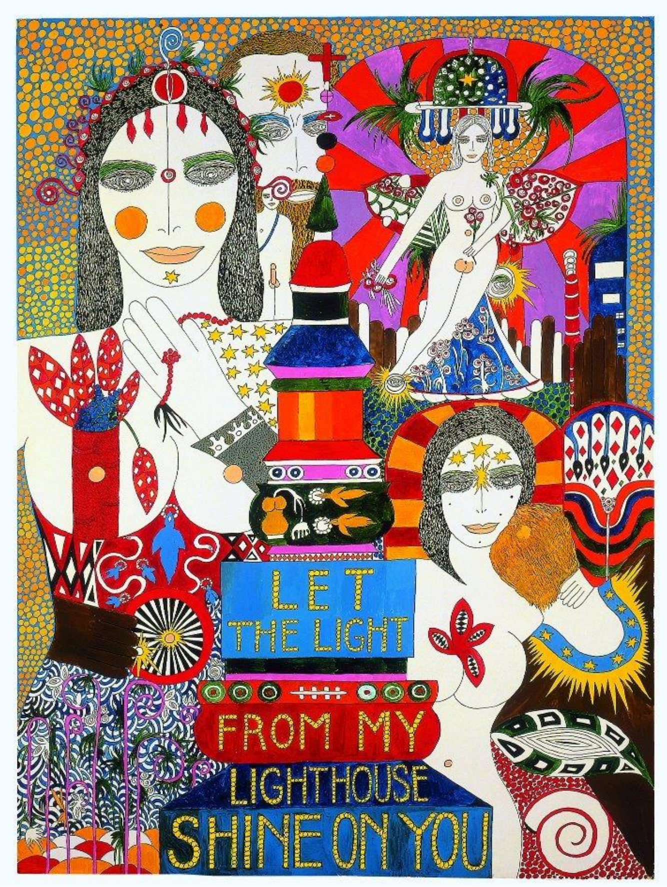
A Lighthouse Doesn't Always Prevent Wrecks

Primo

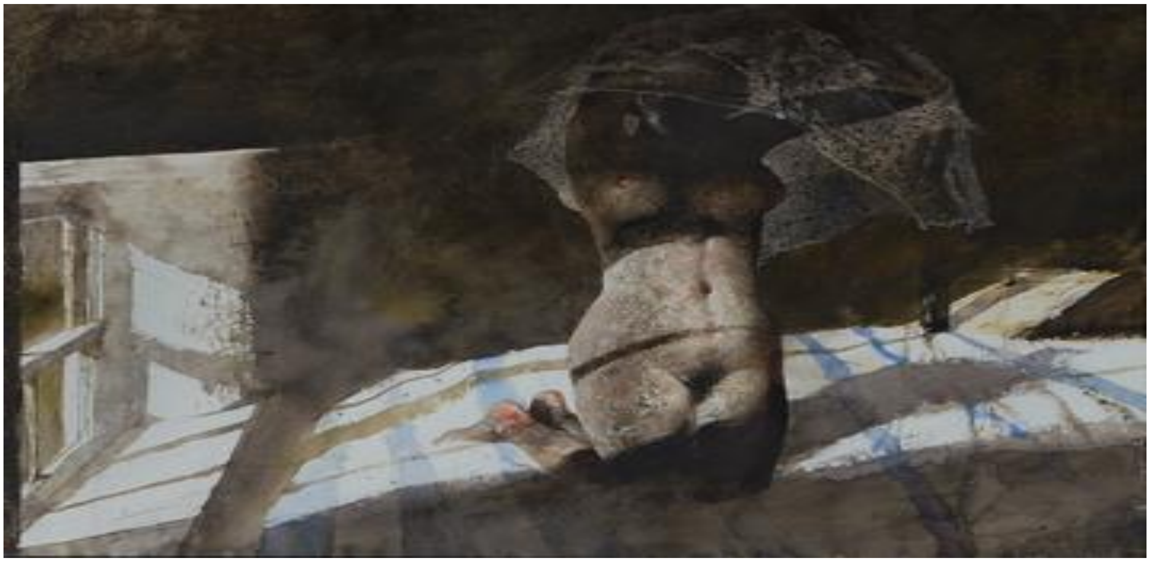


Nude man(can you see the light house?)Henry Tuke

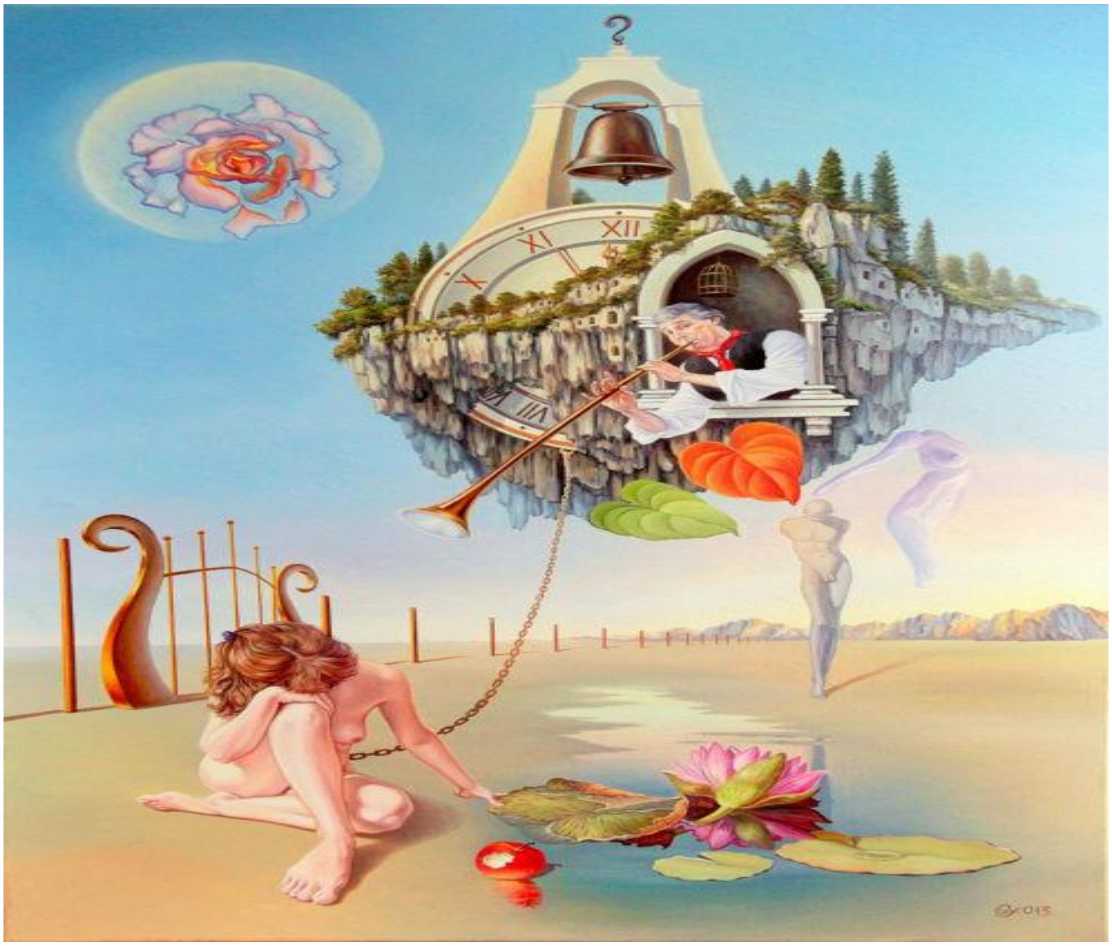
Bromley Davis



Dorothy Lannone



Andrew Wyeth. In the light house



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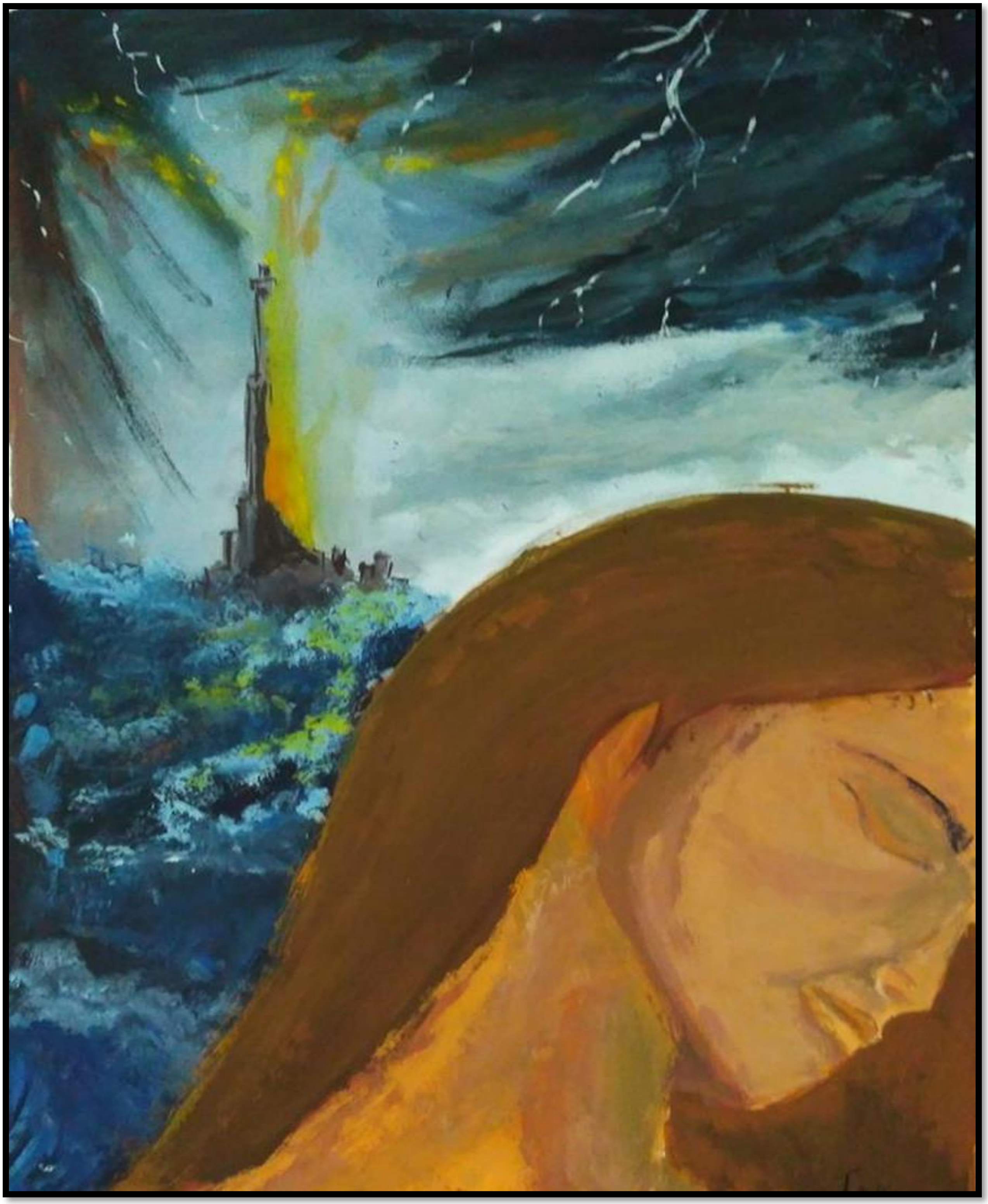
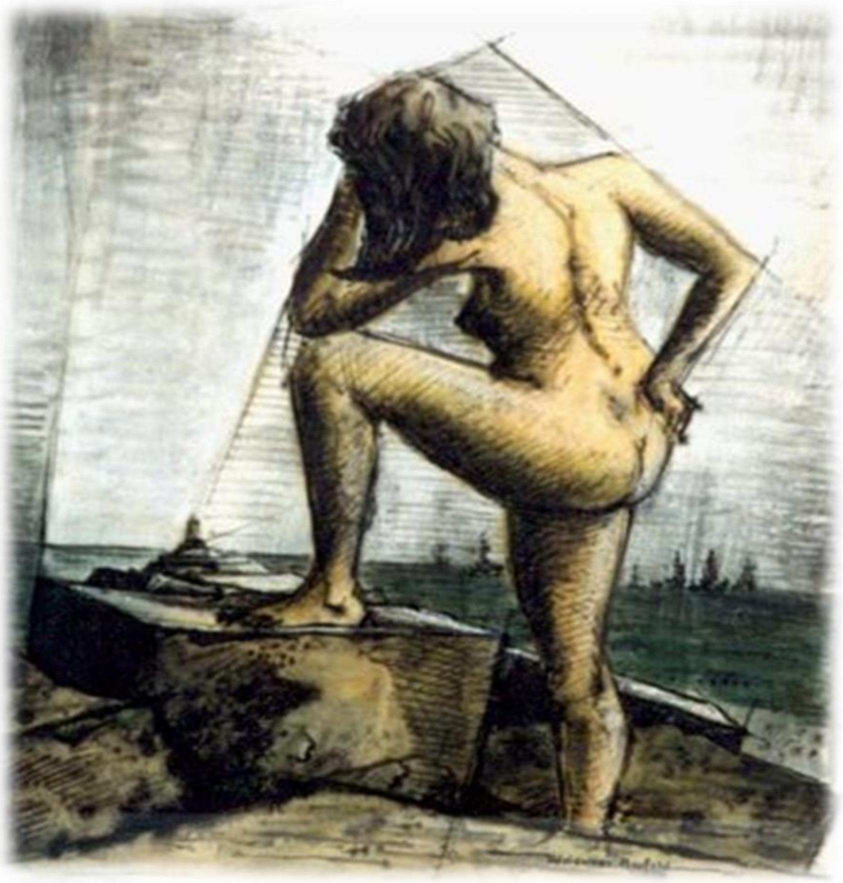


Anirban Kar



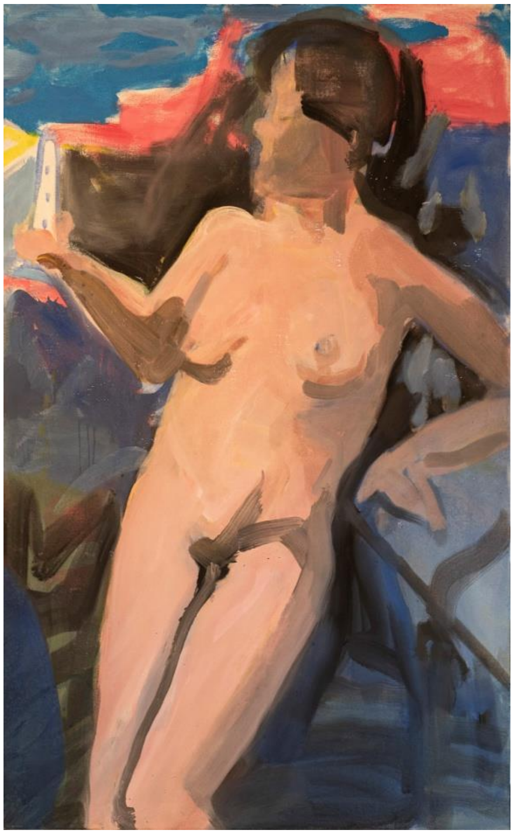
Woldemar Neufeld (1909 - 2002)

LILY C BY LUCA HELIOS :: ORIGINAL FILES UP TO 50MP! :: © MET-ART.COM :: ONLINE SINCE 1999

Oregeon smallest light house. Jordan Jones

Henry Tuke"The Light House"   Nude jumping off Docks

Clementine-Nudes



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